The Use of IR and Visible Station to Monitor and Prevent Sea Coast and Sea Water Pollution in High Risk Sites

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ABSTRACT

We describe the experience gained in the application of thermography coupled to visible sensors for continuous monitoring of coasts subjected to high risk of pollution, especially oil. The intent is to prevent and possibly stop oil or pollution before it arrives to the cost. Our work is based on the idea that recovering oil pollution on sea surface is cheaper and simpler rather than recovering it on the coast. We describe our three pilot experience: airborne analysis of sea coast by helicopters where we analyzed the difference between natural and human water input in sea; artificial oil pollution test in controlled area to study the ability of commercial “low-cost” IR sensor to see and discriminate oil over the water; long-time monitoring with stand-alone station in low and high risk pollution coast, these tests allowed us to study the problem of false-alarm due to boats or other elements.

INTRODUCTION

The use of infrared to monitor the pollution of the sea is a practice used frequently with satellite images and aerial IR application; we intend to develop a less costly solution to prevent costal pollution due to hydrocarbons released into the sea. Our experience teaches us that cleaning up the sea surface from hydrocarbons pollution is cheaper and simpler than cleaning up the coastline from hydrocarbons pollution. Today, infrared analyses are carried out through satellite and / or specific aerial services; these solutions are very expensive and are able to give us a static situation but are unable to give us information about dynamics of the event: the satellite takes only one picture and usually the resolution is not enough to see small pollution areas; the solution with airplanes or helicopters is very expensive to provide a service day by day. Our research began by chance, thanks to a job for regulation and maintenance of an infrared camera that looks at the coast; this job, that involved us for two years, allowed us to analyze a lot of information about the capability of a micro bolometer sensor to be able to see the pollution on the sea surface. This kind of data, outside the scope of our job, allowed us to see that the different emissivity between water and other elements may help us to identify the pollution. Since 2007 we began to seek a solution that could automatically detect the presence of pollutants in the sea. In Sicily the presence of several oil refineries makes particularly interesting the possibility to prevent and avoid pollution of the coasts from these products. The studies that we describe below, and their conclusions, follow the path that we played in the implementation of the prototype system.

STUDIES AND DATA

The basis of our studies involve collection of thermal infrared imagery from an infrared and visible station; from this collection we developed a software solution to detect automatically the presence of pollution in the scene and to determinate if it is really hydrocarbons based or other (Figure1). Our research may be summarized in 3 steps:

1° step: Aerial analysis: To test the ability of the sensor in the detection of water inputs along the coast and discriminate between natural (rivers) and human (discharges)
2° step: Laboratory tests: identification of the main parameters to locate a particular type of pollutant (hydrocarbons and derivatives) and its response in case of thermal variation.
3° step: Prototype: test of the complete system and evaluation of external natural noises; optimization of the system to avoid false alarm.

1 STEP: AERIAL ANALYSIS

Methodology:
To do the test, we previously prepared the flight plan looking for natural and artificial discharges. We carried out a flight along the coast making the analog film infrared and visible addition to the thermal images of the points previously identified like discharges. In post-process have been integrated with the data collected the coordinates of the flight recorded by the GPS system of the helicopter.

Equipment:
Infrared camera:

- Sensor: Microbolometer FPA 160x120 pixel
- Waveband 7,5-13 µm
- Lens: 19°
- Temperature range: -20 / +120 °C
- Emissivity = 1
- Target distance : 320 m

Video camera:

- Sensor: Sony 800,000 pixel
- Recording support: MiniDV

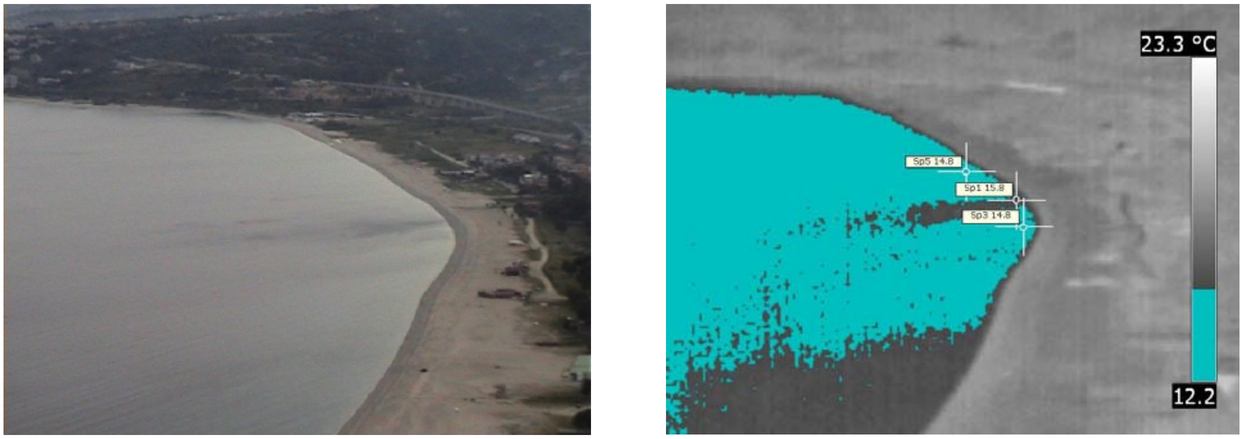
Video server

- Mpeg4 encoder in SD card.

Results:
It was possible to identify the kind of discharges according to their temperature despite the small difference (about 1 °C), the analysis was purely qualitative; natural inputs (rivers) were all detected colder than the sea, unlike the artificial inputs (discharges) were identified at a higher temperature.

a *b*

Figure 1: Natural inputs (rivers) - (a) : Visible image - (b) : Infrared image, the image shows the flow of freshwater into the sea (river), to highlight the area we used the tool isotherm below 17.2 ° C



a *b*

Figure 2: artificial inputs (discharges) - (a) : Visible image, you can see a change in the reflection; - (b) : Infrared image, the image show the release of a small discharge of human origin in the sea, to highlight the area was used the tool isotherm below 15°C

2 STEP: LABORATORY TESTS

The capability of identifying a fluid discharged along the coast and, according to its temperature, to be able to estimate its nature is not sufficient for the purpose of our study; in the case of water or water-soluble product when they reach the same temperature it became invisible to the infrared camera. Tests performed in the lab, using hydrocarbons of different composition, showed a dynamic linked to its chemical nature. The results led to the identification of parameters needed for automatic detection of the possible presence of hydrocarbons pollutant.

<u>Methodology:</u>

Tests were carried out using two hydrocarbons with very different characteristics, gasoline (density 720 kg/m3 @ 15°C) and oil (density: 875 kg/m3 @ 15 ° C). In the lab we reproduce conditions of a real installation with the following data:

Surface: 500 m^2
Incident angle (average) : 20°
Distance (min): 40 m
Distance (max): 100 m

For each test we used 1 ml of hydrocarbon, the following table shows the amount of oil equivalent in the real case and the size of MFOV.

Table 1		
-	Test	Equivalent
hydrocarbon	1 ml	4,4 l
MFOV	3 cm^2	1,5 m^2

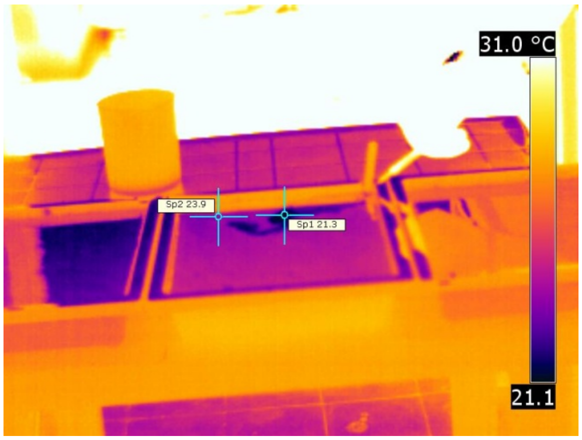
<u>Equipment:</u>

Infrared camera:

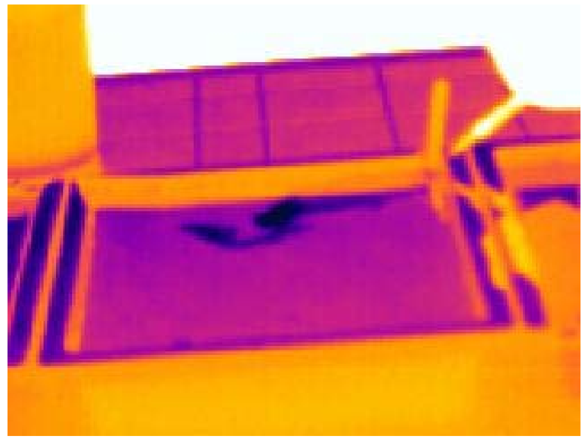
Sensor: Microbolometer FPA 320x240 pixel
Waveband 7,5-13 µm
Lens: 25°
Temperature range: -20 / +120 °C
Emissivity = 1
Target distance : 1,5 m

Test 1 : Isotherm (hydrocarbons temperature = water temperature)

Description: We put 1 ml of hydrocarbon at the same temperature of the water. Figures 3 (gasoline) and 4 (oil) show the start-up and stabilization after 20 minutes.



3.1a



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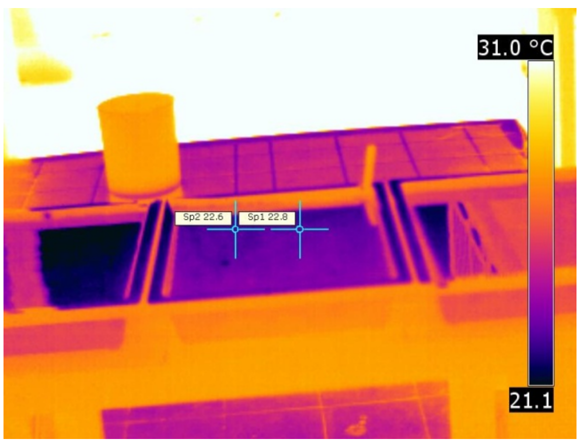
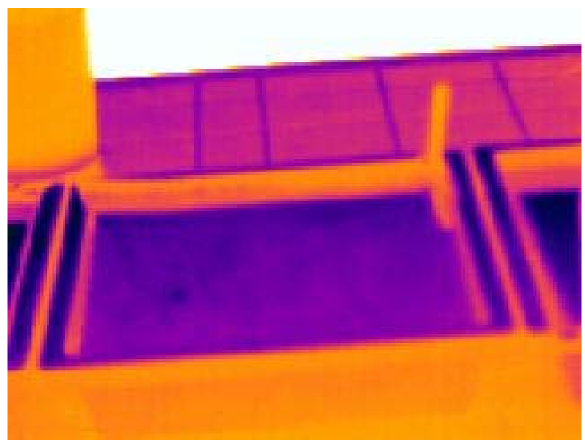
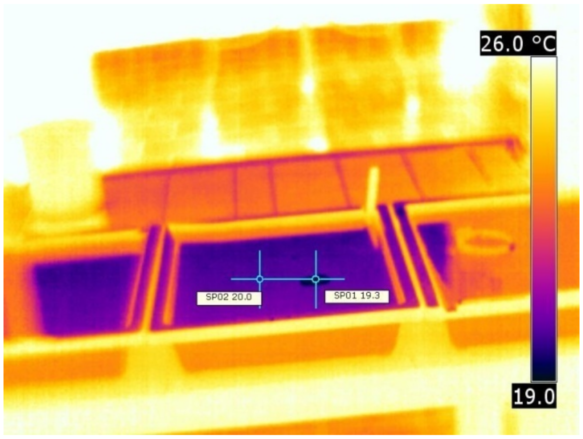


3.2a



3.2b

Figure 3: Isotherm tests with gasoline - 3.1 : (a) the gasoline is seen as black fluid; the lower surface tension of gasoline leads to immediate expansion on the surface of the water (broken contours) (b) zoom - 3.2 : (a) 20 minutes after the gasoline cover the surface completely and isn't detectable (b) zoom.



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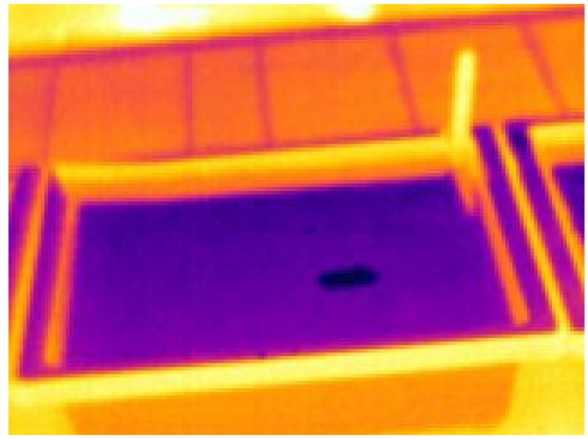

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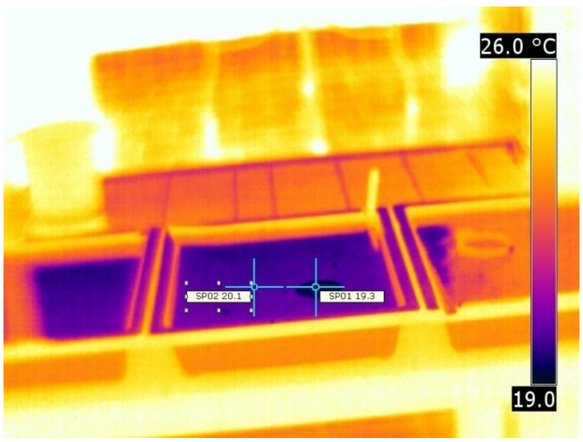
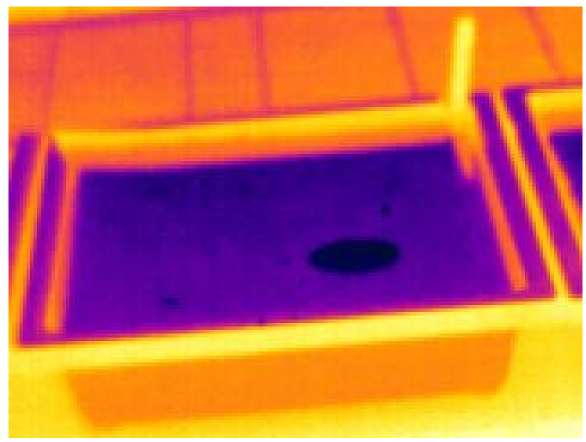


4.2a

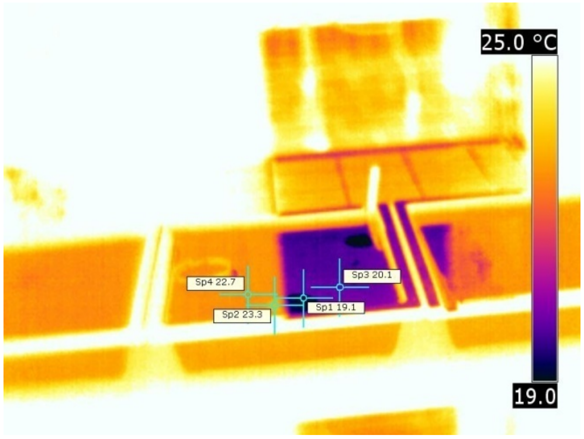


4.2b

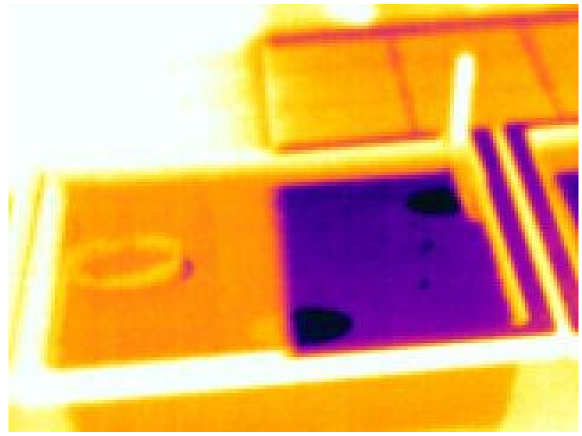
Figure 4: Isotherm tests with oil - 4.1 : (a) the oil is seen as black fluid; the highest surface tension leads to an expansion of oil on the surface of many compounds (circular contours), (b) zoom - 4.2.: (a) 20 minutes after the oil remain composed: (b) zoom

Results:

a) The different emissivity between water and hydrocarbon results in a greater reflection of the background with relative increase of the "contrast" in complex images. Figure 5 shows an example:



a



b

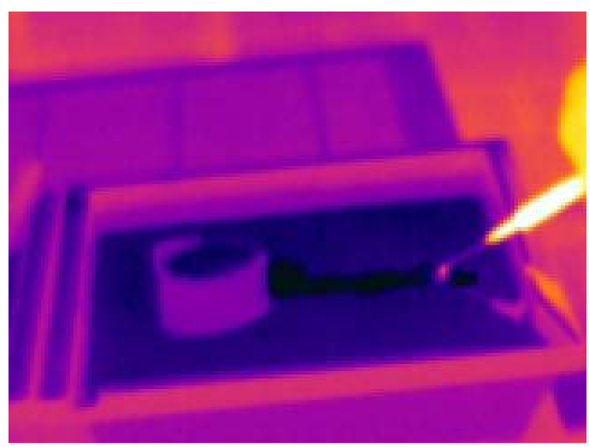
Figure 5: (a) you can see the difference in response of hydrocarbon (spot at the bottom), on the left side was used a warm background (panel), on the right side the reflective element is the sky. The hydrocarbon seems hotter on the left (panel) and coldest in the right (the sky). (b) zoom

b) To allow an automatic analysis we need a source of reflection as uniform as possible (the sky is the best background);
c) It must always be an area with clean water, when the hydrocarbon completely covers the area analyzed (gasoline) is no longer possible to locate;
d) The difference in thickness has a marginal influence on the sensor;

Test 2: Hot hydrocarbon (Hydrocarbon Temperature > Water Temperature)

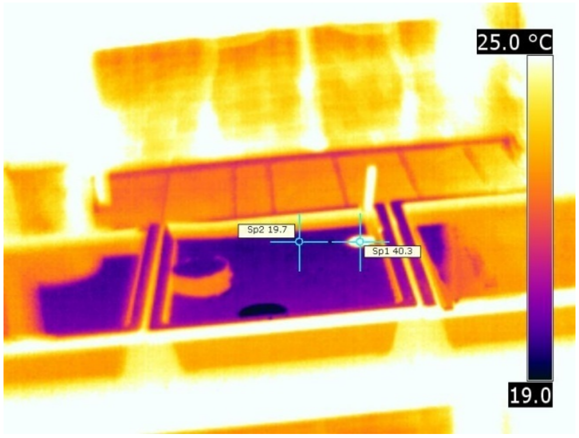
Description: hydrocarbons were released at a temperature higher than water of about 20°C, Figures 5 and 6 show, respectively for gasoline and oil, start-up and the thermal balance.

a

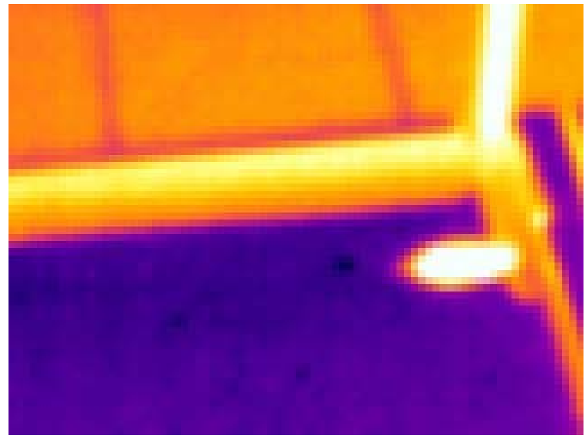


b

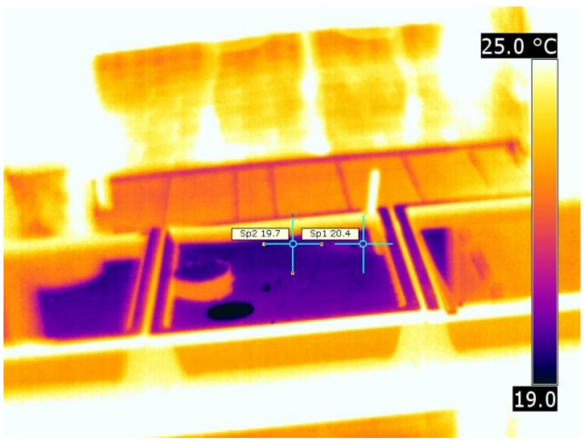
Figure 6: gasoline : (a) temperature apparently falls to 18 °C with an average water temperature of 20°C. The circle to the left is a sample of clean water. (b) zoom.



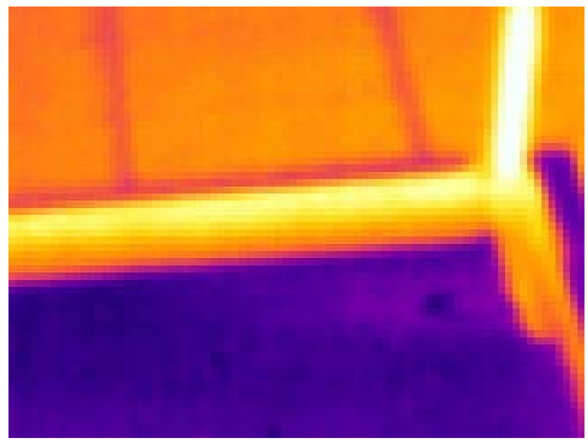
7.1a



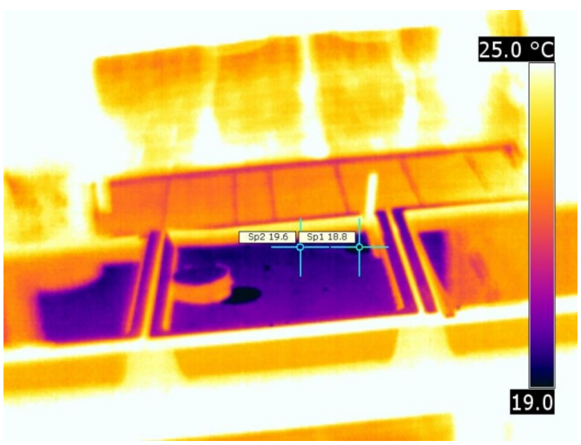
7.1b



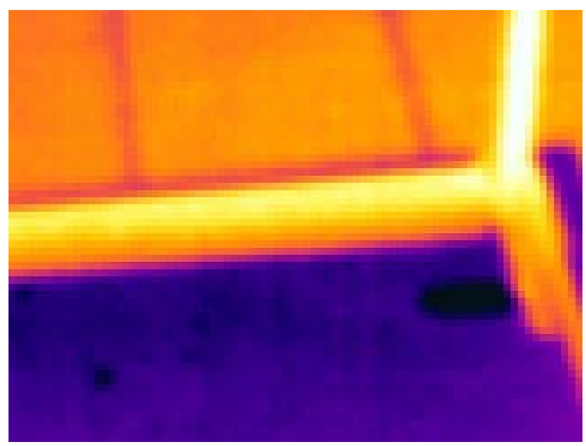
7.2a



7.2b



7.3a



7.3b

Figure 7: Oil - 7.1: (a) at start-up we can see the difference based on temperature (b) zoom - 7.2: (a) at about 1 minute oil reaches the same radiosity as the water and became invisible (b) zoom - 7.3: (a) after few seconds temperature decreasing allow to see oil again thanks to different emissivity (increasing of reflectivity) (b) zoom

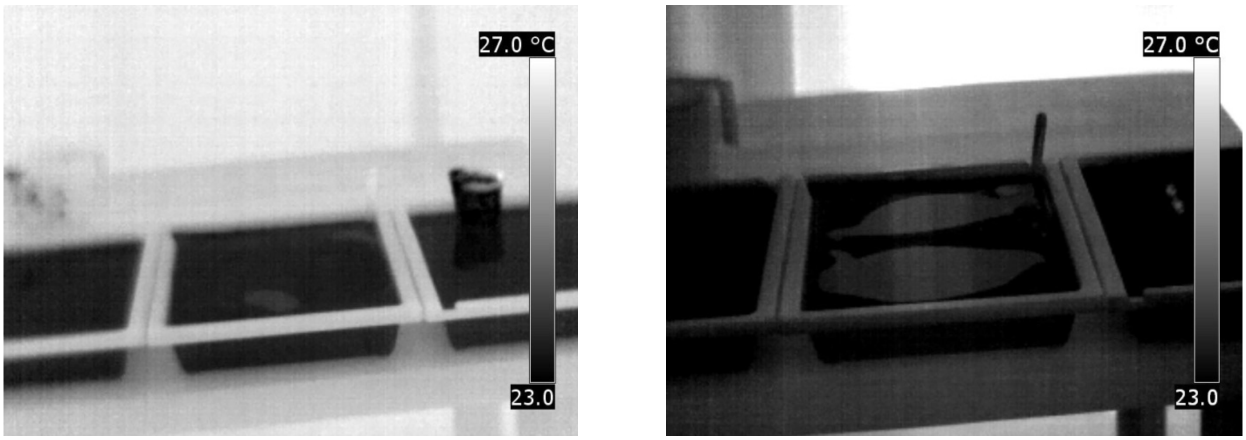
Results:

a) The volatile hydrocarbons such as gasoline does not show a particular difference with the test 1 and are spread more rapidly on the surface becomes invisible after a few minutes.

b) The less volatile hydrocarbons as oil will be initially identify for the higher apparent temperature and only after reaching thermal equilibrium will be identifiable by their different emissivity.

__Test 3 : Durability__

Description: have been taken several images of the same sample of oil (2 ml divided in two areas), respectively, to 0.5 - 5 - 24 - 40 hours from start-up, Figure 8 shows the most relevant images.



a *b*

Figure 8: Durability (hot background) (a) it is possible to identify the two spots of oil at 0.5 hours after the start-up. (b) at 40 hours it is possible clearly see the spots oil expanded on the surface of the water.

Results:
Test confirms the possibility to individuate hydrocarbons with low volatility even after 40 hours of their release into the sea.

3 STEP : PROTOTYPE

As a result of activities conducted in the lab, experimental software has been prepared for real-time analysis of infrared images and generation of alarms in case of pollution detection. We installed an IR and visible station in front of a seaport with the intent to identify the environmental factors that are not reproducible in the laboratory and test the automatic alarm system. Figure 9 shows the test area for the prototype; the area is equivalent to the one simulated in the lab.

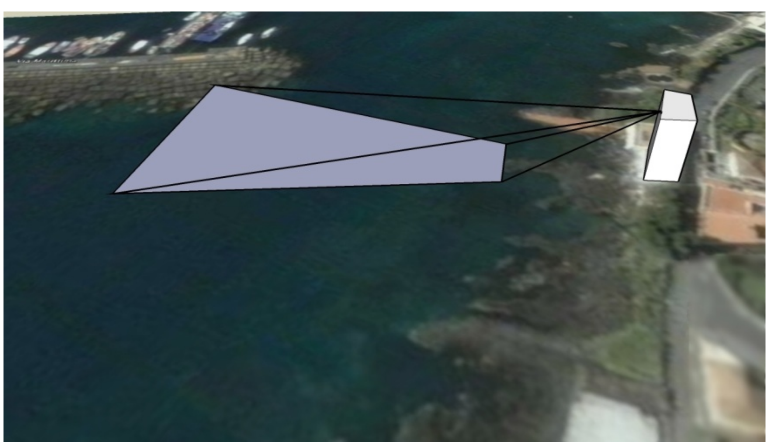


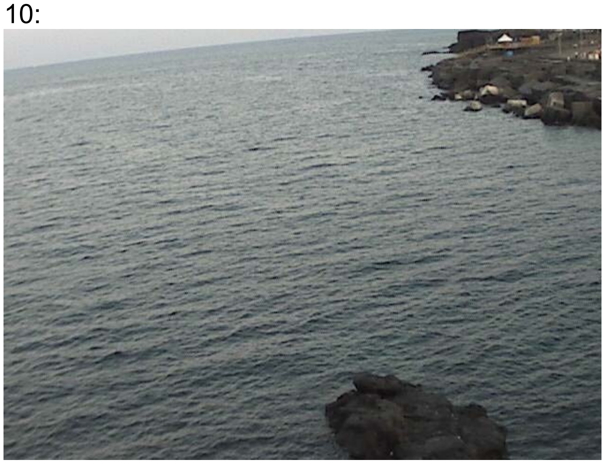
Figure 9: Test area

<u>Methodology:</u>
We proceeded step by step, during first period we studied infrared images to define environmental parameters that can fool the alarm system; then during the executive test, our software developer optimize the software to avoid false alarms mainly due to the passage of boats. During the test we rotate the station to view different areas and to look for pollution; actually it was not simple to find someone that leave gasoline or oil in the sea.

<u>Equipment:</u>
Infrared camera:
- Sensor: Microbolometer FPA 320x240 pixel
- Waveband 7,5-13 μm
- Lens: 25°
- Temperature range: -20 / +120 °C
- Emissivity = 1
- Target distance : 60 m (average)

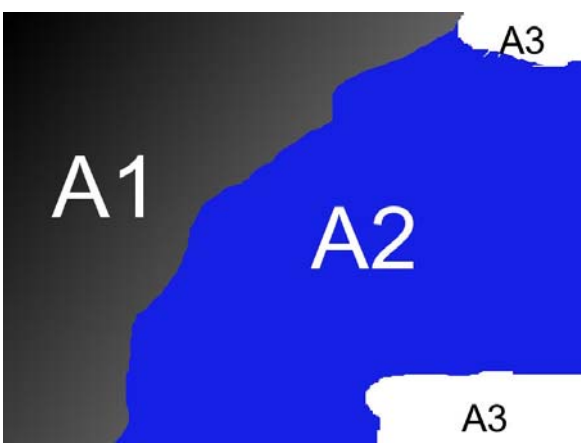
Video:
- Sensor: Sony 800,000 pixel

<u>Results</u>:
Within the image we found several areas with different thermal responses related to both the nature of the subject (eg. the presence of discharges) and the angle of incidence. To obtain good results we needed to calibrate the software accordingly with this difference. We defined three main areas as you can see in Figure 10:



a

b



c

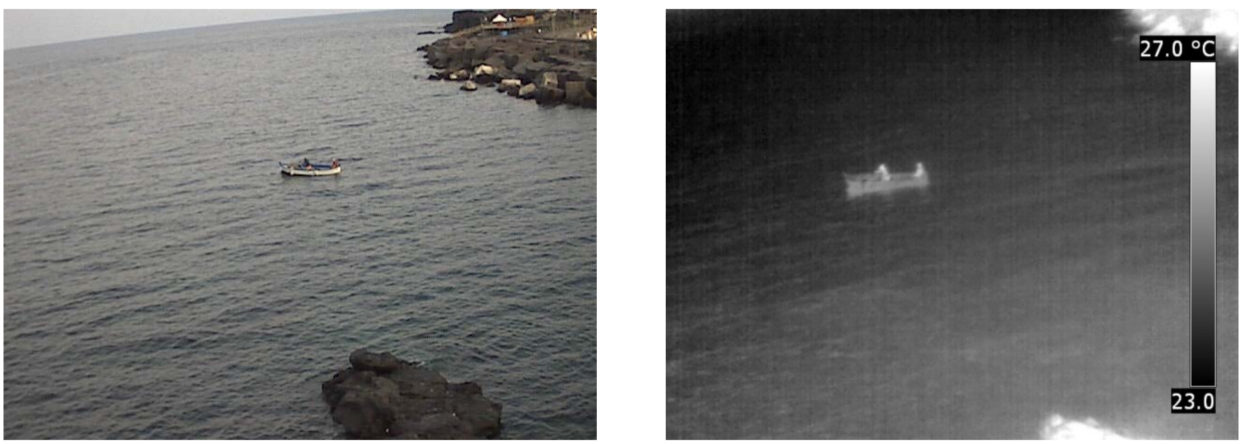
Figure 10: Identification of areas with different thermography response (a) visible image (b) infrared image, you can identify 3 areas A1 - A2 - A3; only A1 and A2 are subject to analysis. (c) mask with indication of areas.

After this we needed to calibrate the software to avoid false alarm due to boat and boat's tracks; a motor boat has a hot track that expands and cools rapidly as shown in Figure 11

a *b*

Figure 11: fishing boat (a) visible image (b) infrared image, you can find the track of hot water released from the engines.

A sailing boat (or rowing boat) causing a track with low thermal variations and a persistence of few seconds. An example is show in Figure 12.



a *b*

Figure 12: rowing boat (a) visible image (b) infrared image.

A motor boat that releases hydrocarbons (gasoline in this case) into the sea causing a track cold and persistent as you can see in Figure 13

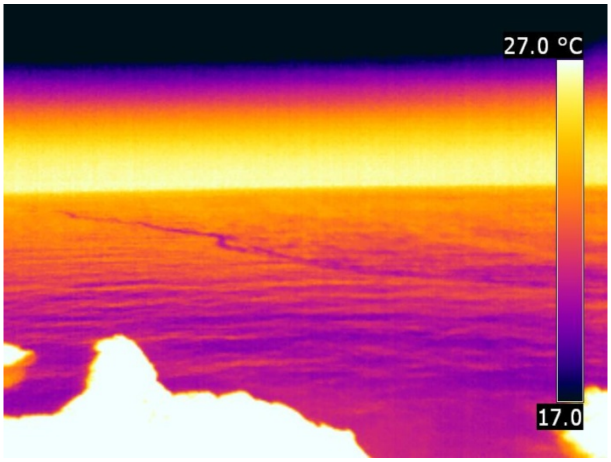


Figure 13: Gasoline's track due to motor boat.

Software response and start-up time

The software automatically generates alarms, creating a database with information on the event including:
- History with visible and infrared images
- Real-time communication to team control
- Streaming real-time video signals (visible and infrared)

To obtain reliable results a calibration time was necessary, according to the environmental parameters linked to place and season. At the end of calibration the prototype was able to give us only 3% of false alarm with good weather and 50% with bad weather conditions (covered sky, rain etc...)

SUMMARY

With the results obtained and with the help our prototype software, we develop a project in close collaboration with the existing structures for the control of the coast in order to avoid that hydrocarbon-based pollutants reach the same. The automatic system will communicate directly with the team, which will act immediately either to the verification of the type of hydrocarbon that any remediation activities.

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Giovanni Distefano (1973) working with thermography from 2004, He's qualified at level 2 NDT operator according to UNI EN473:2001 ISO 9712 rules in the thermograph methods; from 2007 he started to study the application of thermography in environmental controls focused on pollution. Today he is working in IMC Service srl searching and developing IR solution for their services.