Measurement of wildfire geometrical parameters by drones

Vito Ciullo, Lucile Rossi

UMR CNRS 6134
Sciences Pour l'Environnement
Université de Corse

https://feuxdeforet.universita.corsica

SPE UMR
CNRS 6134

GT UAV, 21 Juin 2019, Marseille

Università di Corsica Pasquale Paoli

UMR CNRS 6134 Sciences for the Environment
Forest Fire Project

SPE UMR CNRS 6134

UMR CNRS 6134

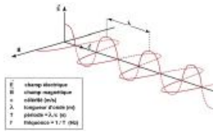
6 research projects

- Water management and recovery in the Mediterranean

- Natural resources

- Renawable energy

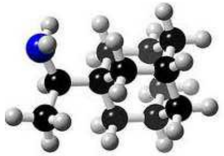
- Information and communication technology



- Wavefields and applied mathematics

- **Forest Fire**

Forest Fire Project



- 20 researchers at the University of Corsica

  Chemistry, ecology, physics, vision, computer science

- Study and modelling of fire behavior

$$\left.\begin{array}{l} |U_n| > u_0 \tan|\alpha| \Rightarrow \tan\beta = \frac{U_n \cos^2\alpha}{u_0 + U_n \sin\alpha\cos\alpha} \\ |U_n| \leq u_0 \tan|\alpha| \Rightarrow \tan\beta = \frac{\tan\alpha}{1+2\tan^2\alpha} \end{array}\right\}$$

$$\left.\begin{array}{l} \gamma \leq 0 \Rightarrow r = 1 \\ \gamma > 0 \Rightarrow r\left(1-\frac{1}{r}\right)^3 = A^3(1+\sin\gamma-\cos\gamma)^3 \end{array}\right\}$$

- Development of fire-fighting and land-use tools

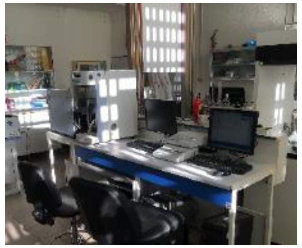
https://feuxdeforet.universita.corsica

Università di Corsica Pasquale Paoli

Platforms

SPE UMR CNRS 6134







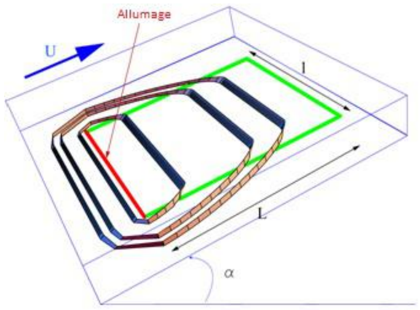




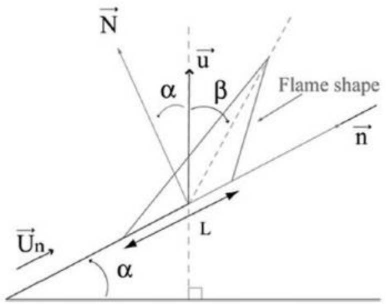

Need of experimental data

SPE UMR
CNRS 6134

- To understand the phenomena
- To improve or/and validate numerical models



- State of a fire at a given time: its geometrical characteristics



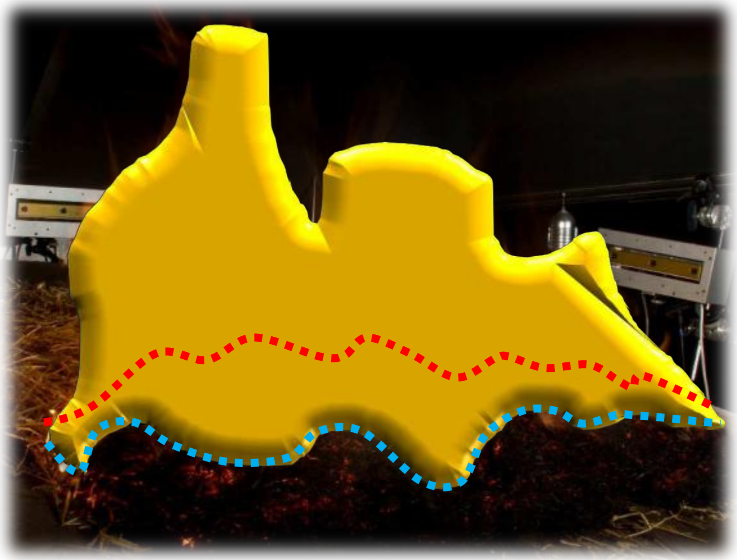
- At several scales: laboratory, semi-field and field

UNIVERSITÀ DI CORSICA PASQUALE PAOLI

Geometrical characteristics

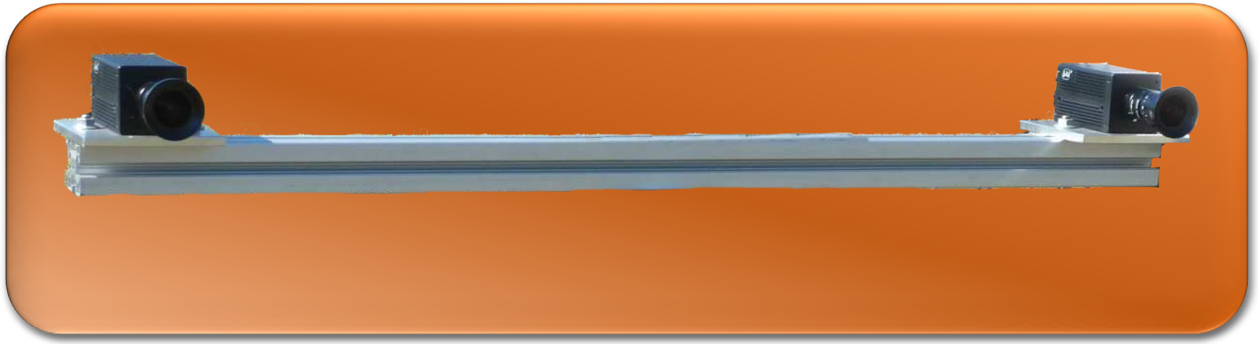
SPE UMR CNRS 6134

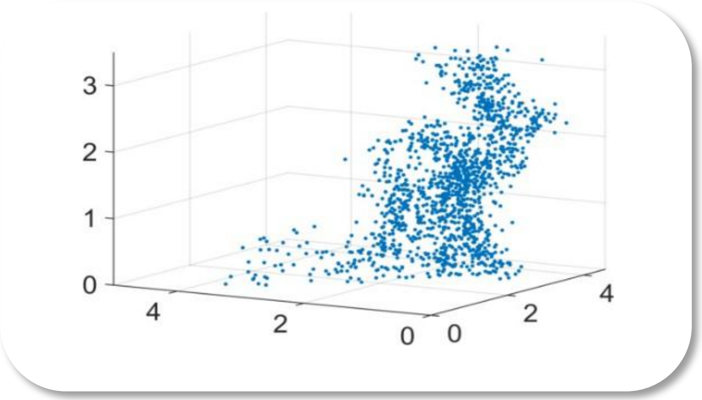
- Position on the ground
- Height
- Length
- Inclination
- Width
- Speed
- Surface
- Volume

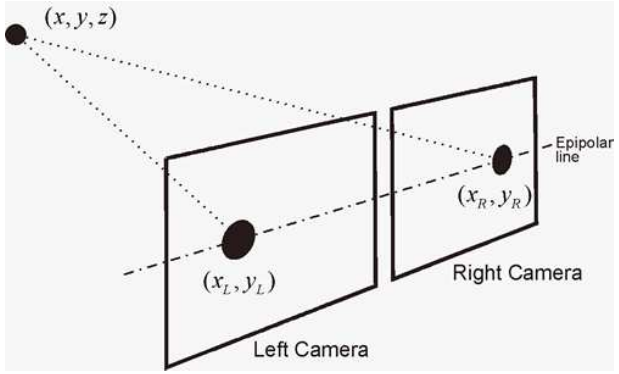


3D data obtained by stereovision

SPE UMR
CNRS 6134





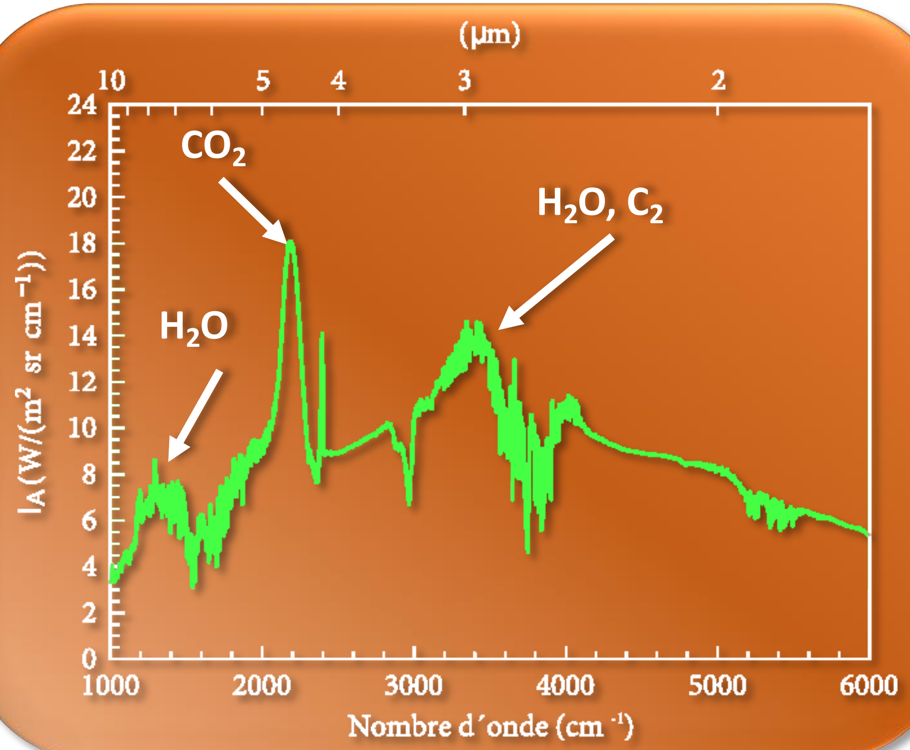


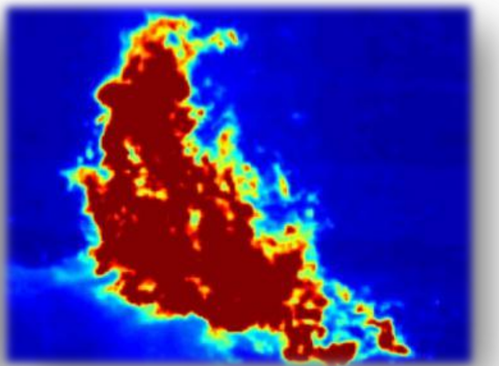
Università di Corsica Pasquale Paoli

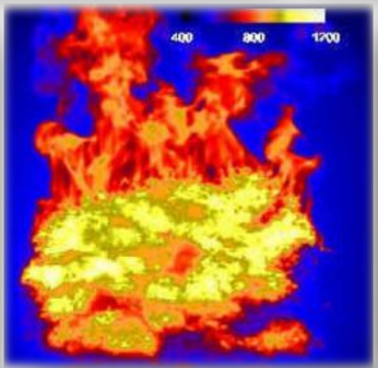
Electromagnetic emissions and vision of fire in different spectra

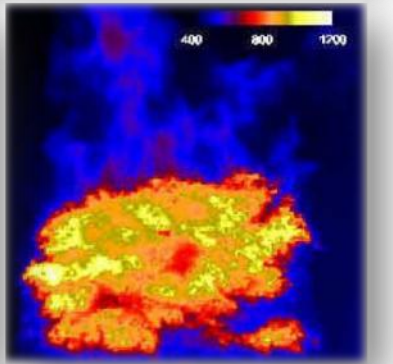
SPE UMR
CNRS 6134

- Combustion process
- High temperatures (400°C to 1500°C)
- Gases : CO_2, H_2O
- Solids : soots, embers, ashes



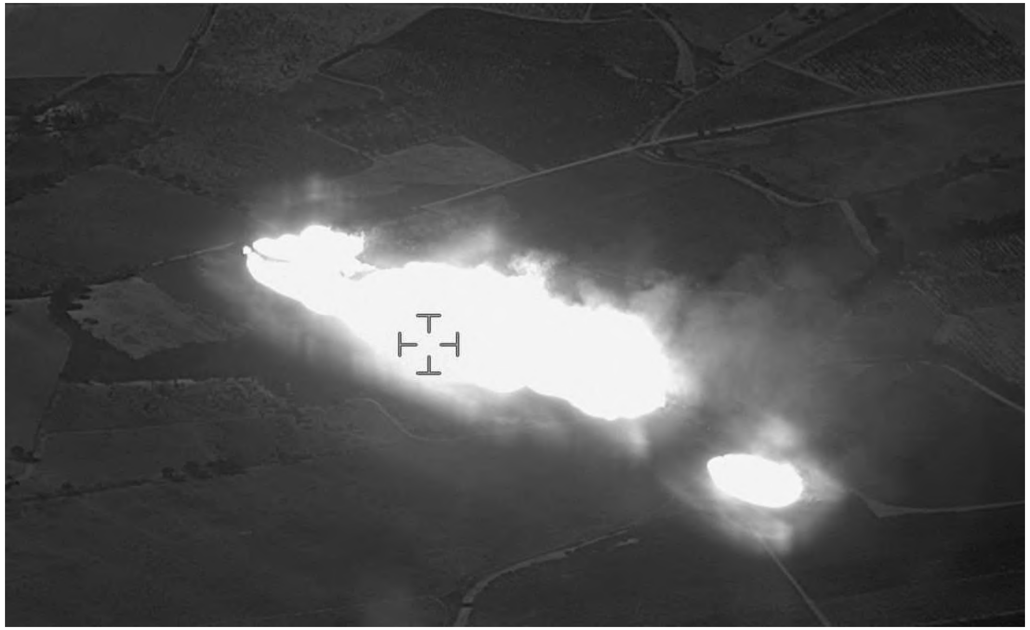






Images of a spreading fire in the visible and infrared spectra

SPE UMR
CNRS 6134



Università di Corsica Pasquale Paoli

Detection of fire pixels in the visible domain

SPE UMR
CNRS 6134

- **Visible domain: reference**

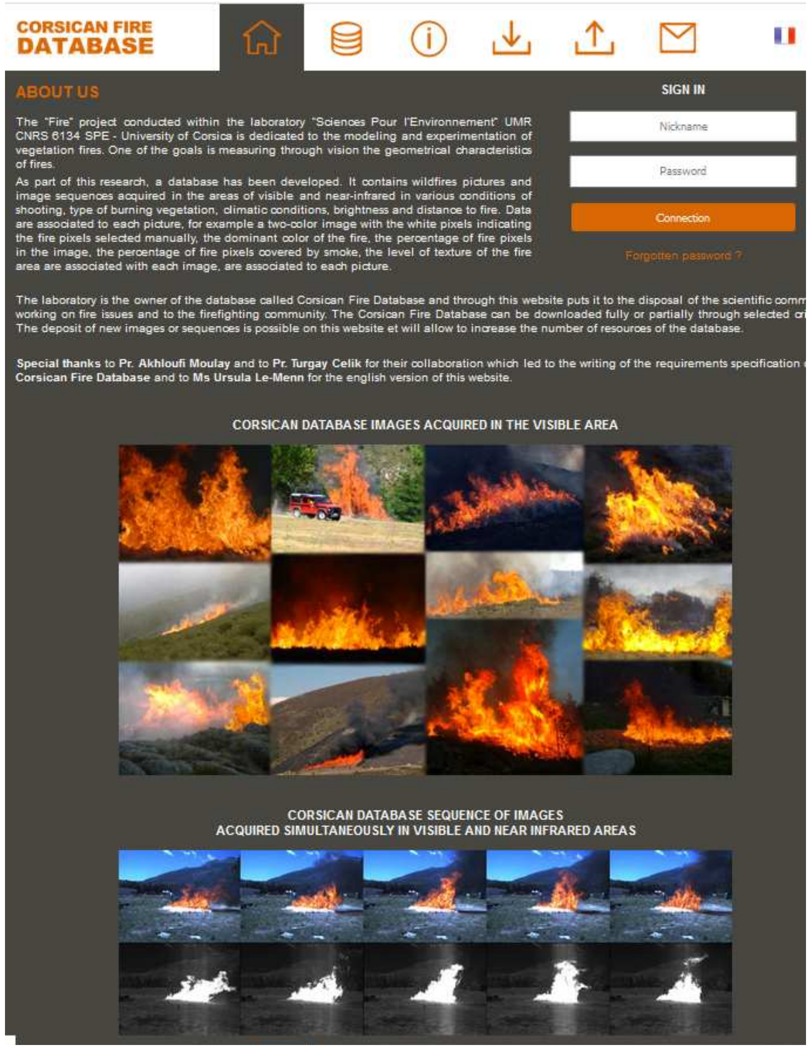
- **Heterogeneous colors**
- **Different textures**
- **Smoke**

- **A lot of research on this subject**

UNIVERSITÀ DI CORSICA PASQUALE PAOLI

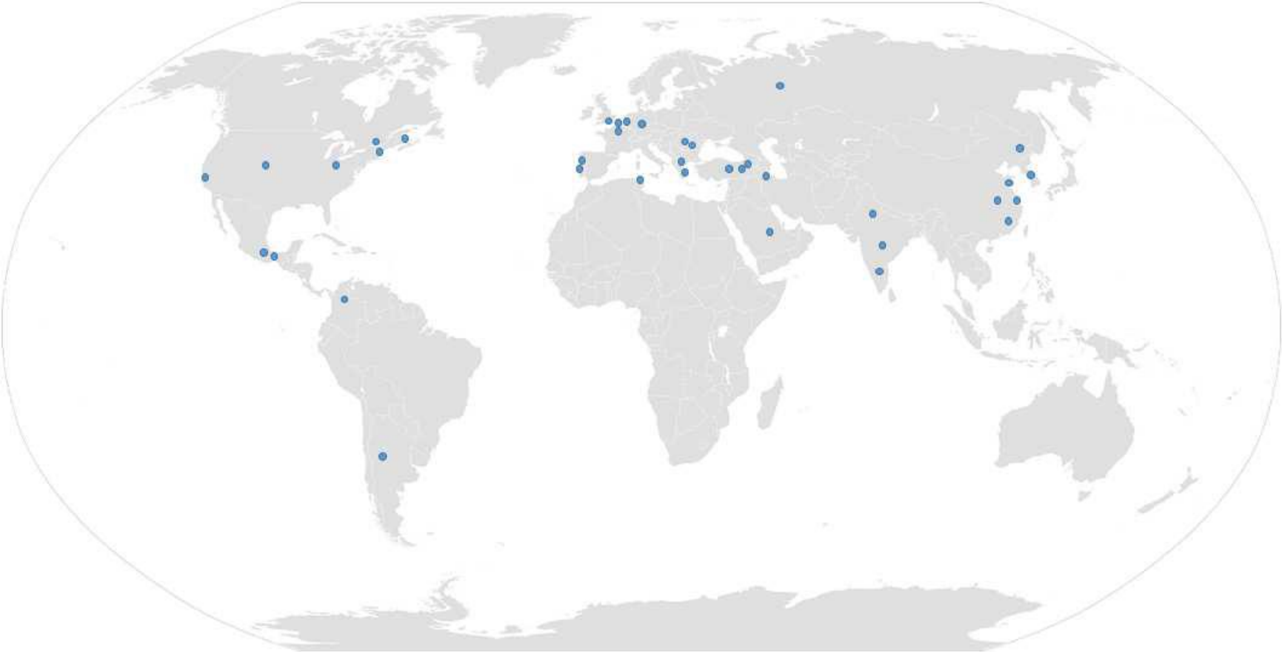
Corsican Fire database

SPE UMR
CNRS 6134



http://cfdb.univ-corse.fr/

More than 50 accounts have been created

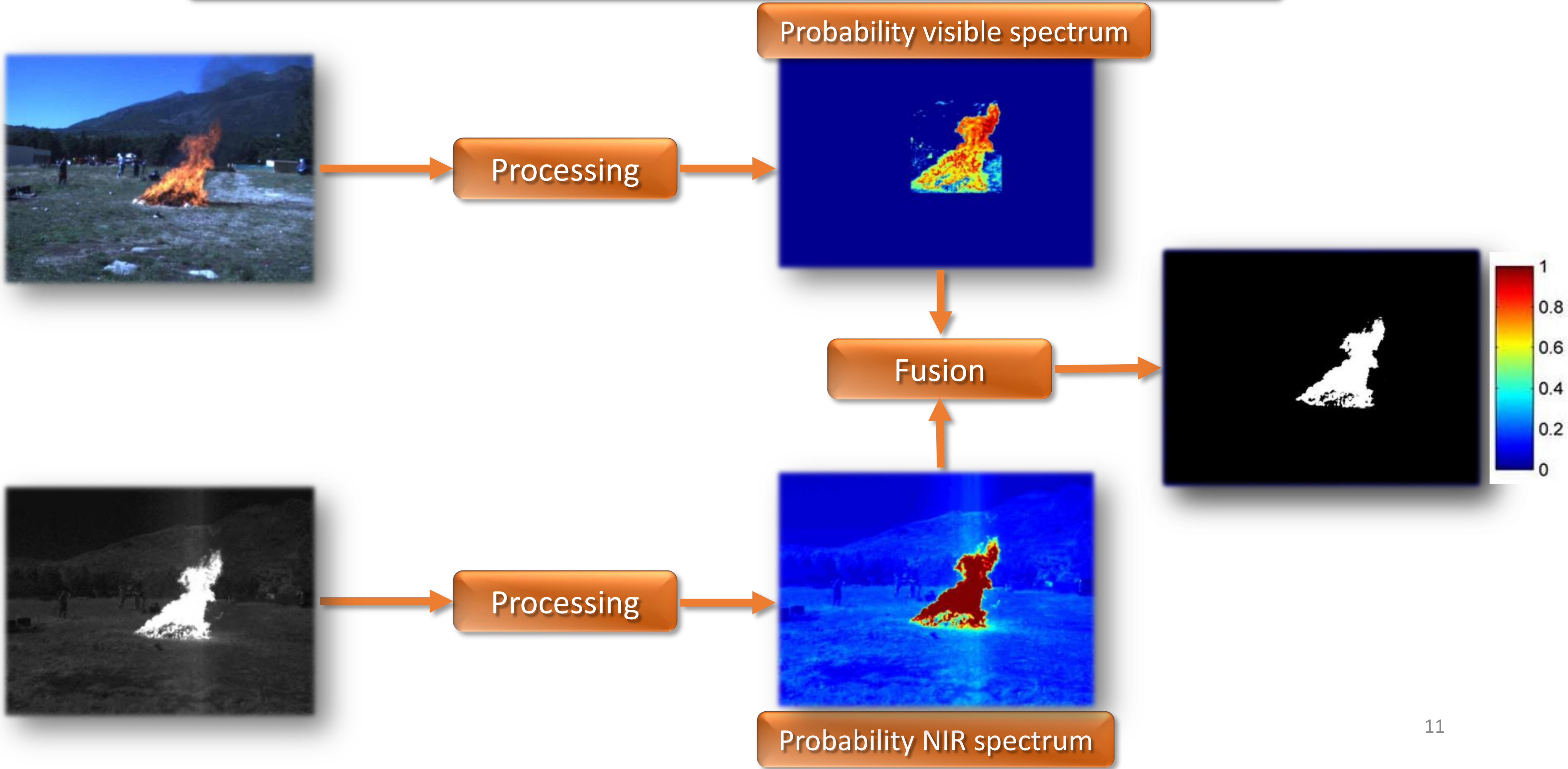


Computer vision for wildfire research: an evolving image dataset for processing and analysis, T. Toulouse, L. Rossi, A. Campana, T. Celik, M. Akhloufi, Fire Safety Journal, 92, 188-194, 2017, 10.1016/j.firesaf.2017.06.012

Università di Corsica Pasquale Paoli

SPE UMR
CNRS 6134

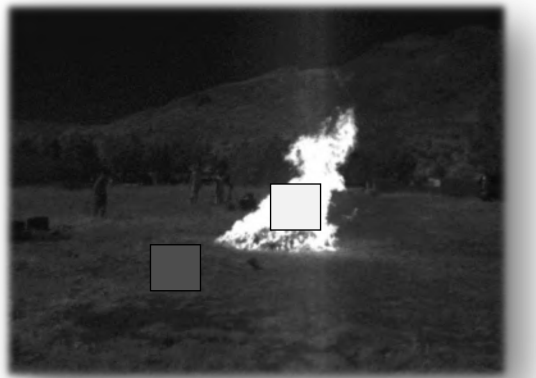
Multimodal fire detection by result fusion



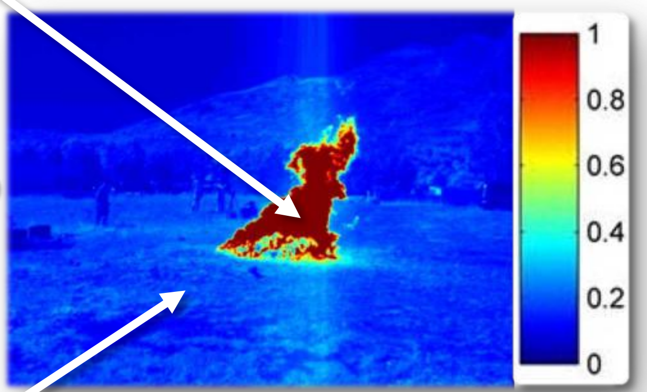
Probability associated to each pixel of an infrared image

SPE UMR
CNRS 6134

$$p(\text{feu}|x) = \frac{x - t}{2(255 - t)} + \frac{1}{2}$$



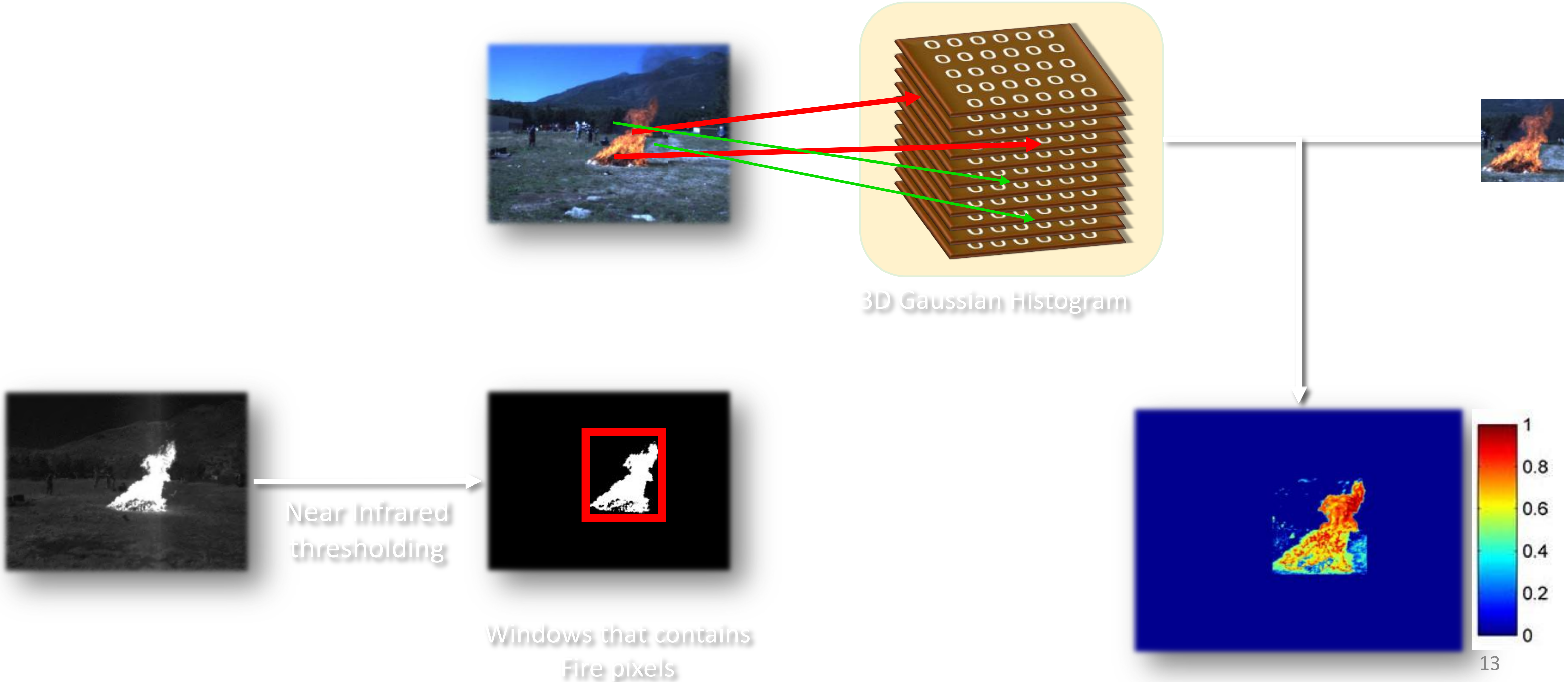
> threshold ?



$$p(\text{feu}|x) = \frac{x - t}{2t} + \frac{1}{2}$$

Probability associated to each pixel of a visible image

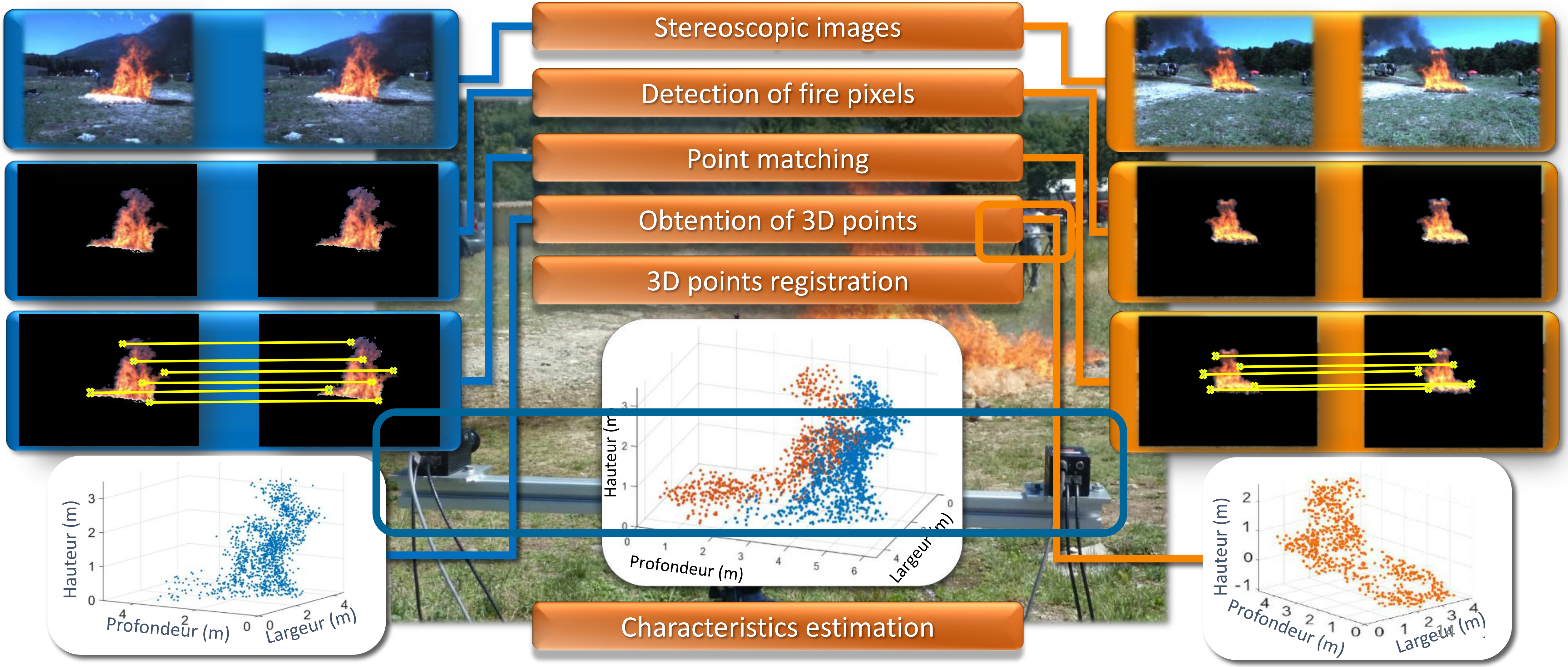
SPE UMR
CNRS 6134



Università di Corsica Pasquale Paoli

Fire measurement by stereovision

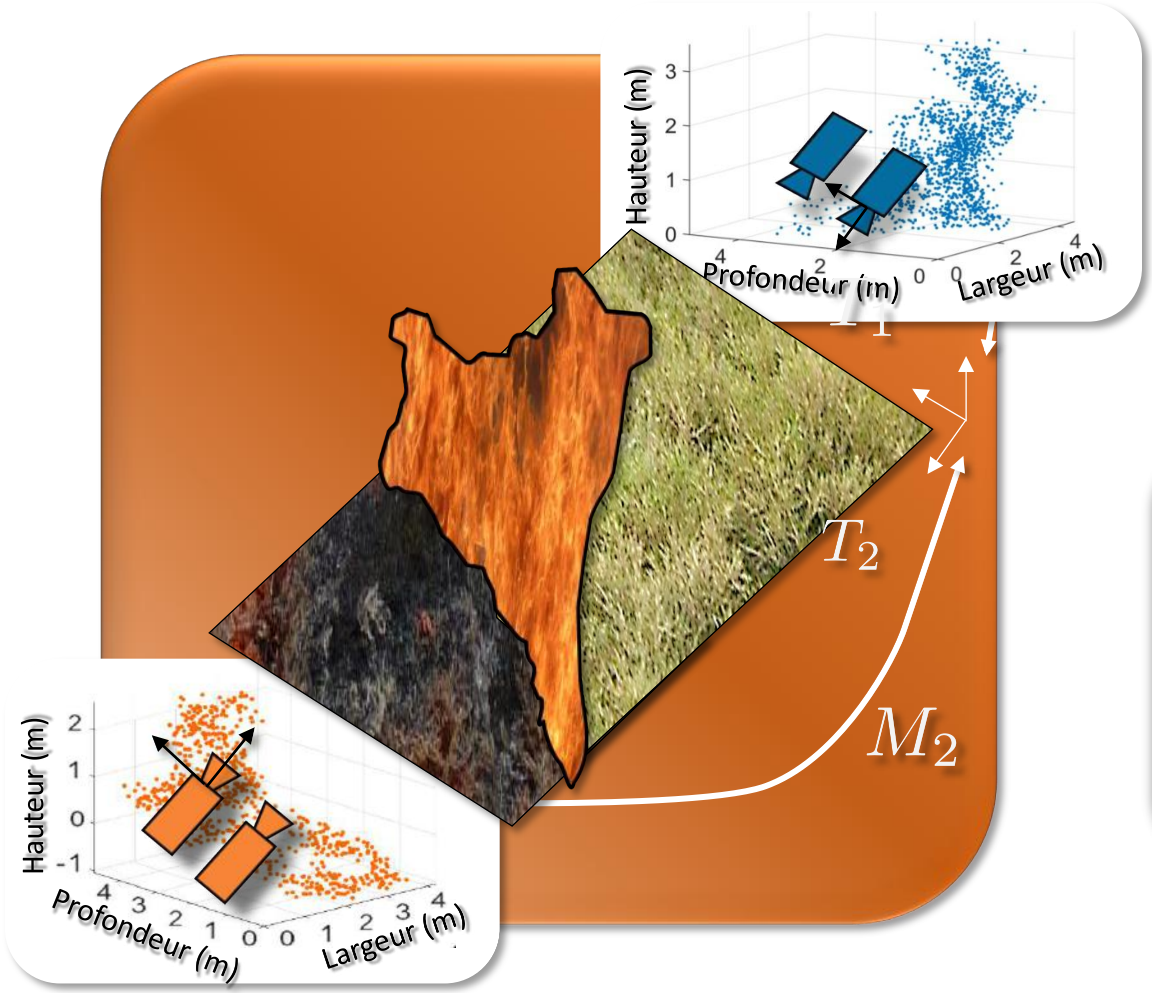
SPE UMR
CNRS 6134



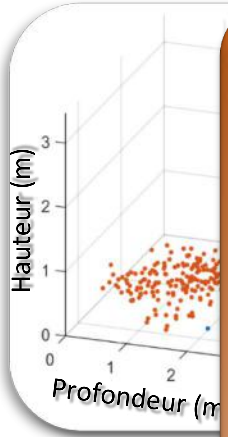
Università di Corsica Pasquale Paoli

SPE UMR CNRS 6134

Registration of 3D points Obtained from the various stereovision systems



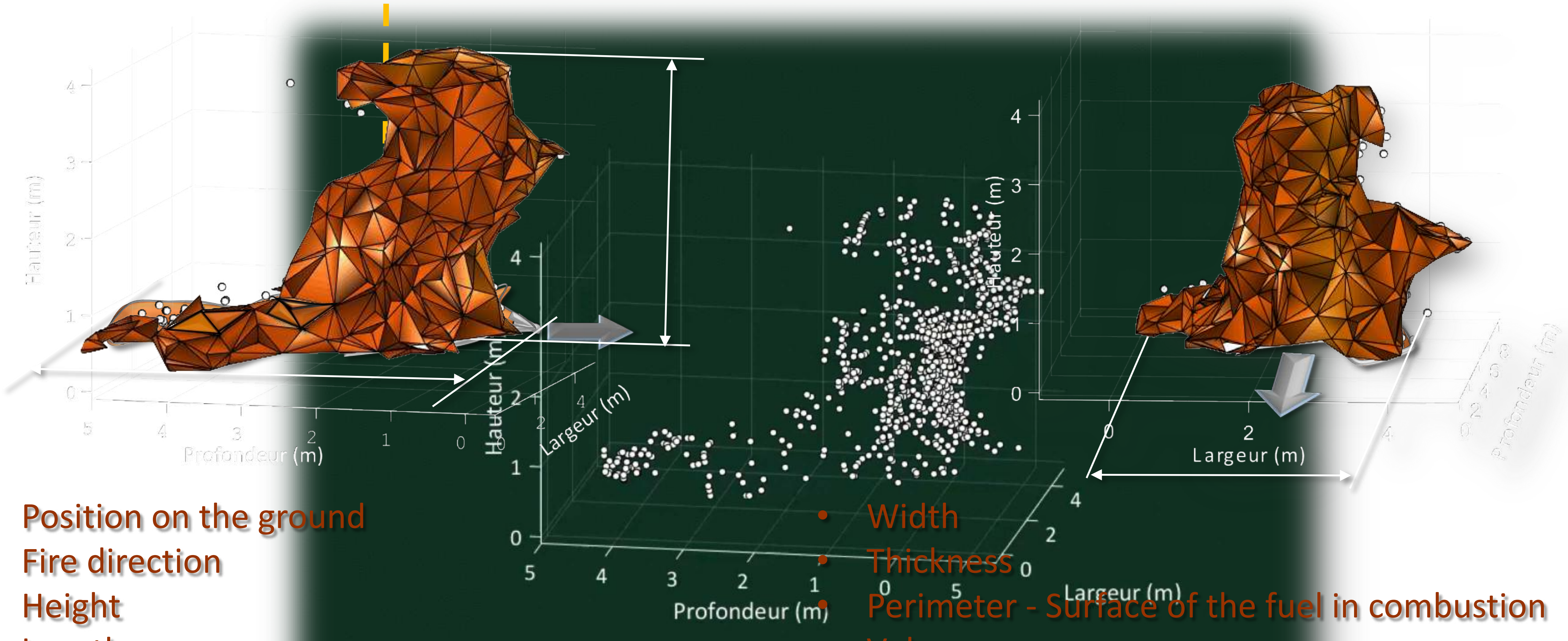
Flight controller of the AR Parrot UAV



GPS Leica Viva CS10 receptor with RTK system

Fire geometrical characteristics estimation

SPE UMR
CNRS 6134



- Position on the ground
- Fire direction
- Height
- Length
- Inclination

- Width
- Thickness
- Perimeter - Surface of the fuel in combustion
- Volume

Università di Corsica Pasquale Paoli

Prescribed fires

SPE UMR
CNRS 6134




Difficult camera placement on the ground

- No access
- High vegetation

Difficulty to anticipate the fire travel and to position the cameras

Great distances traveled

Idea → **Use of UAV**

Use of drone to detect and monitor fires

SPE UMR
CNRS 6134

SDIS 40 Landes
Fly N Sense society
2010

SDIS 13 Bouches du Rhône
2017
NOVADEM society

United States

Detection, monitoring and measurement of forest fire by UAV

SPE UMR
CNRS 6134

2005

2005 American Control Conference
June 8-10, 2005. Portland, OR, USA

FrA04.5

Forest Fire Monitoring With Multiple Small UAVs

David W. Casbeer
Randal W. Beard
Timothy W. McLain
Brigham Young University

Sai-Ming Li
Raman K. Mehra
Scientific Systems Company, Inc.

Abstract— **Frequent updates concerning the progress of a forest fire are essential for effective and safe fire fighting. Since a forest fire is typically inaccessible by ground vehicles due to mountainous terrain, small Unmanned Air Vehicles (UAVs) are emerging as a promising means of monitoring large forest fires. We present an effective UAV path planning algorithm utilizing infrared images that are collected on-board in real-time. To demonstrate the effectiveness of our path planning algorithm in realistic scenarios, we simulated the propagation of a forest fire with the EMBYR model. A new cooperative control mission concept is indroduced where multiple Low-Altitude, Short-Endurance (LASE) UAVs are used for fire monitoring. By emplying multiple UAVs, the effectiveness of the mission in terms of information update rate can be improved dramatically.**

I. Introduction

Forest fires cause billions of dollars in damage to property and the environment every year. To combat forest fires effectively, early detection and continuous tracking is vital. Many methods have been developed to detect remote forest fires using satellite images [1], [2]. Such images are taken

EMBYR in Simulink, which generates the time-evolution of a typical forest fire. We also introduce a new cooperative control mission concept utilizing multiple LASE UAVs to monitor the perimeter of the fire. By using multiple UAVs, the effectiveness of the mission in terms of the information update rate can improve dramatically. On the other hand, new problems such as coordination of UAV paths to cover the most critical areas, when and which UAV should be taken down for refueling, and how to measure the performance of the entire fleet of UAVs, must be addressed.

The paper is organized as follows: The fire monitoring problem is described in Section II, followed by a description the fire simulation model in Section III. Section IV describes the fire perimeter tracking algorithm used, with simulation results. Section V describes our cooperative control approach using a simplified scenario where the fire is assumed to be of circular shape. Finally, Section VI concludes the paper with comments on future work.

II. Problem Statement

2015

783

NRC Research Press

REVIEW

A survey on technologies for automatic forest fire monitoring, detection, and fighting using unmanned aerial vehicles and remote sensing techniques

Chi Yuan, Youmin Zhang, and Zhixiang Liu

Abstract: Because of their rapid maneuverability, extended operational range, and improved personnel safety, unmanned aerial vehicles (UAVs) with vision-based systems have great potential for monitoring, detecting, and fighting forest fires. Over the last decade, UAV-based forest fire fighting technology has shown increasing promise. This paper presents a systematic overview of current progress in this field. First, a brief review of the development and system architecture of UAV systems for forest fire monitoring, detection, and fighting is provided. Next, technologies related to UAV forest fire monitoring, detection, and fighting are briefly reviewed, including those associated with fire detection, diagnosis, and prognosis, image vibration elimination, and cooperative control of UAVs. The final section outlines existing challenges and potential solutions in the application of UAVs to forest firefighting.

Key words: forest fire, fire monitoring, detection, and fighting, image processing, remote sensing, unmanned aerial vehicles.

Résumé : Étant donné qu'ils sont rapidement manœuvrables, qu'ils ont un grand rayon d'action opérationnel et qu'ils offrent une meilleure sécurité pour le personnel, les véhicules aériens sans pilote (UAV) équipés de systèmes de vision ont un potentiel énorme pour surveiller, détecter et combattre les feux de forêt. Au cours de la dernière décennie, la technologie de lutte contre les feux de forêt qui utilise des UAV s'est avérée de plus en plus prometteuse. Cet article présente un aperçu complet des progrès actuels dans ce domaine. D'abord, une brève revue du développement et de l'architecture des systèmes de surveillance, de détection et de combat des feux de forêt qui utilisent des UAV est présentée. Ensuite, les technologies reliées à la surveillance, à la détection et au combat des feux de forêt sont brièvement passées en revue, incluant celles qui sont associées à la détection, au diagnostic et au pronostic des feux, à l'élimination de la vibration des images et au contrôle coopératif des UAV. La dernière section décrit les défis actuels et les solutions potentielles liés à l'utilisation des UAV dans la lutte contre les feux de forêt. [Traduit par la Rédaction]

Mots-clés : feu de forêt, surveillance, détection et combat des feux, traitement des images, télédétection, véhicules aériens sans pilote.

2011

OPEN ACCESS

sensors

ISSN 1424-8220
www.mdpi.com/journal/sensors

Article

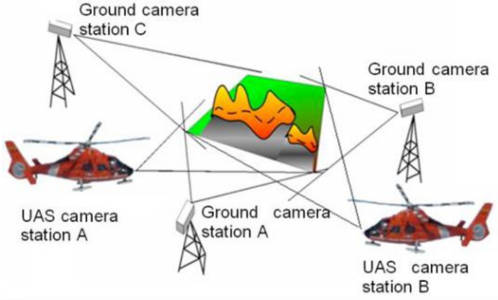
Automatic Forest-Fire Measuring Using Ground Stations and Unmanned Aerial Systems

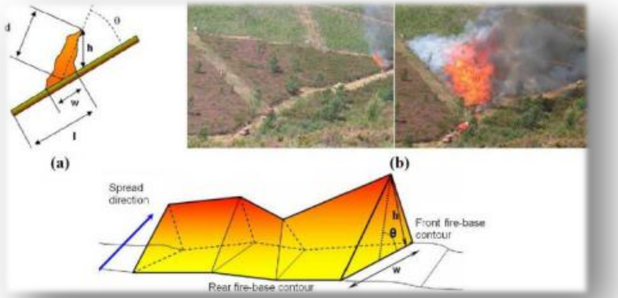
José Ramiro Martínez-de Dios [1,*], Luis Merino [2], Fernando Caballero [1] and Aníbal Ollero [1,3]

1 Robotics, Computer Vision and Control Group, Universidad de Sevilla, Seville, 41092, Spain; E-Mails: fcaballero@us.es (F.C.); aollero@cartuja.us.es (A.O.)
2 Robotics, Computer Vision and Control Group, Pablo de Olavide University, Seville, 41013, Spain; E-Mail: lmercab@upo.es
3 Centre for Advanced Aerospace Technology (CATEC), Seville, 41309, Spain

* Author to whom correspondence should be addressed; E-Mail: jdedios@cartuja.us.es; Tel.: +34-954-487-357; Fax: +34-954-487-340.

Received: 1 April 2011; in revised form: 31 May 2011 / Accepted: 2 June 2011 / Published: 16 June 2011





2019

Journal of Intelligent & Robotic Systems
February 2019, Volume 93, Issue 1–2, pp 337–349 | Cite as

Learning-Based Smoke Detection for Unmanned Aerial Vehicles Applied to Forest Fire Surveillance

Authors | Authors and affiliations

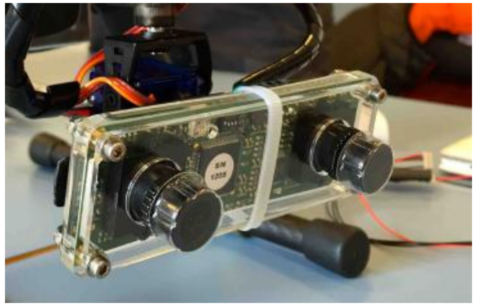
Chi Yuan, Zhixiang Liu, Youmin Zhang

Article
First Online: 28 March 2018

Università di Corsica Pasquale Paoli

Measurement of wildfire geometrical characteristics by UAV

SPE UMR CNRS 6134



- **Work started in 2015**
- **Continuity of works using stereovision**

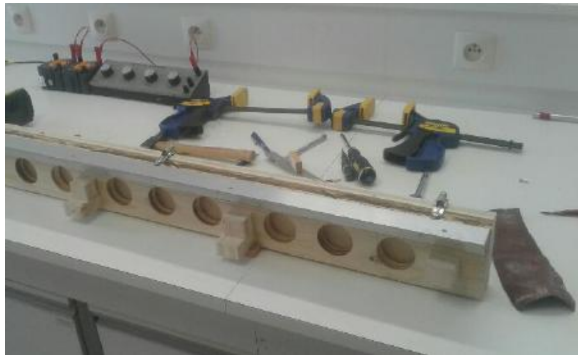
- **Ongoing PhD thesis on this subject run by M. Vito Ciullo**
  - **Distance Fire - Drone: about 15 m**
  - **UAV never flies over of the fire**
  - **Post-processing**

➢ **Development of a stereovision system portable by drone**

➢ **Measurement of the geometrical characteristics of a fire propagating on an unknown sloping ground of about 100 m²**

Development of a stereovision system and assembly on drone

SPE UMR
CNRS 6134



Leopard Imaging camera
LI-OV4689-MIPI
2.8 mm focal length
1280 x 800 pixels
Synchronisation

Theoretical error

$$\Delta z = \frac{z^2}{B\,f}\Delta d$$

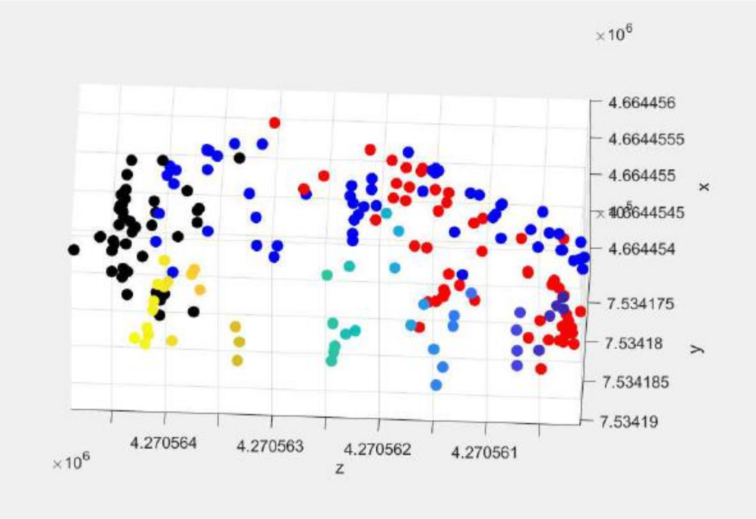
At 15 m, $\Delta z = 0.3$ m

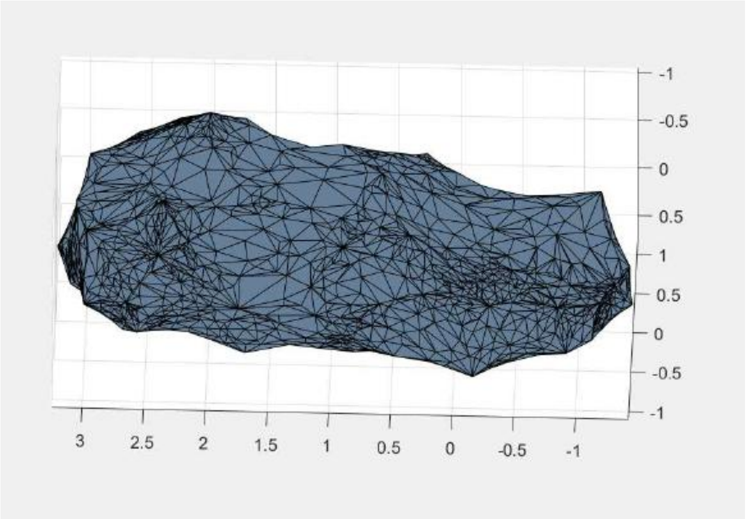
- Baseline = 0.9 m
- Weight = 2.6 kg

Calibration procedure

Ground truth

SPE UMR
CNRS 6134

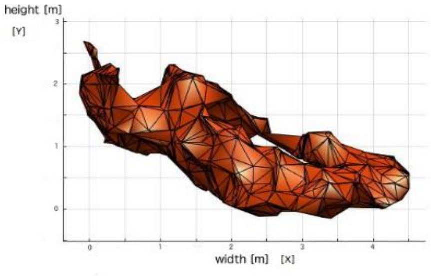


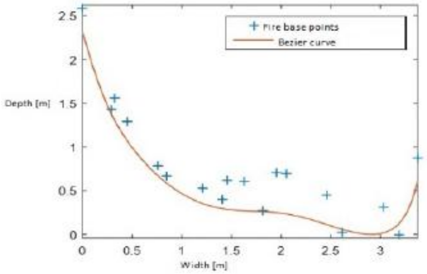


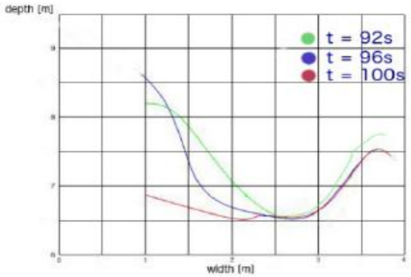
Canonical case

SPE UMR
CNRS 6134

3 x 5 m fuel area
No propagating fire
Position of the fire is known







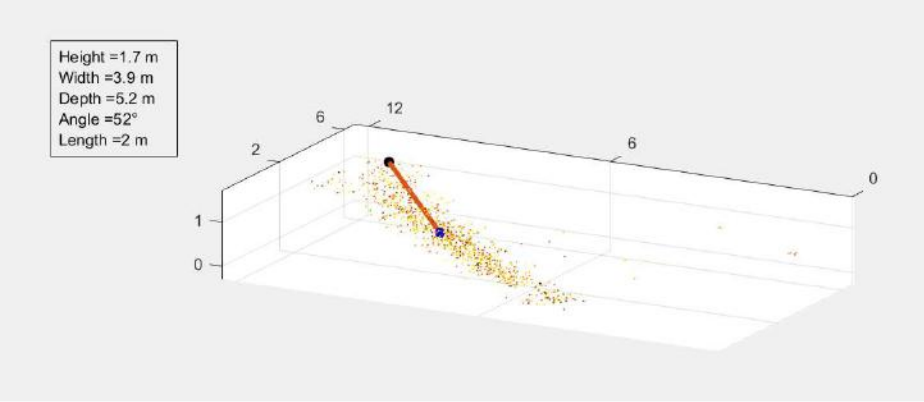
Propagating fire experimental setup

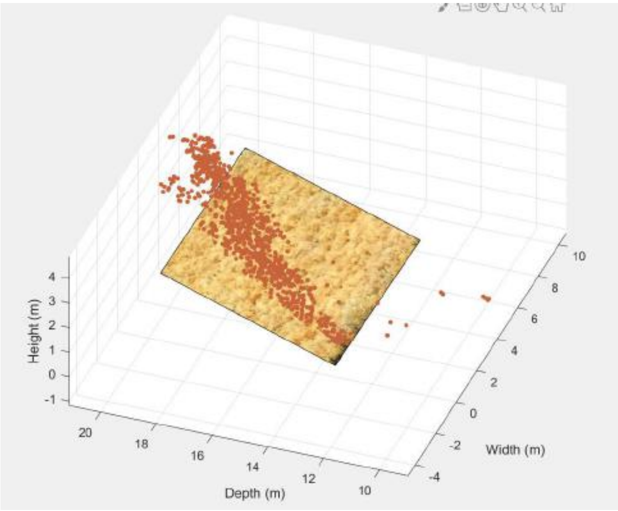
SPE UMR
CNRS 6134

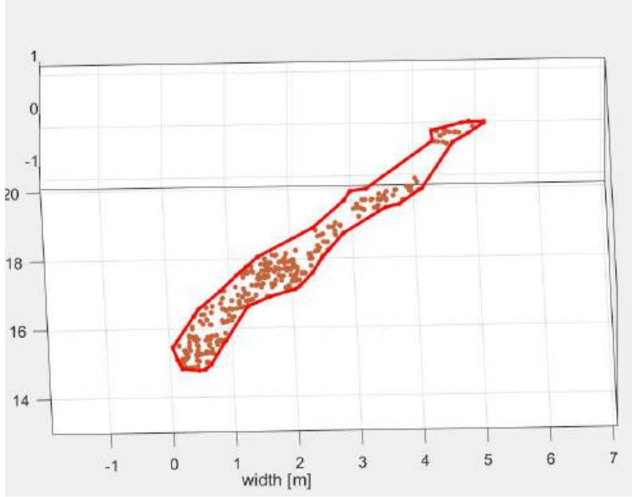
Università di Corsica Pasquale Paoli

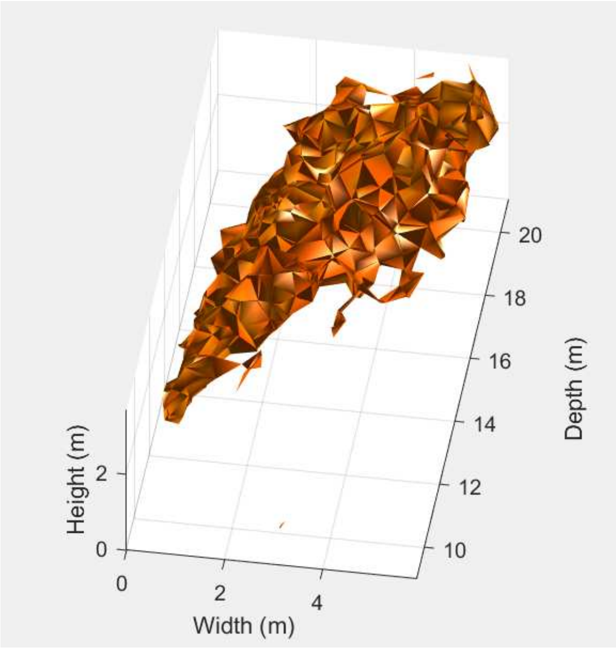
Measurement of propagating fire geometrical characteristics by drone

SPE UMR
CNRS 6134









SATT Sud Est
Pre-maturation

SPE UMR
CNRS 6134

1st Price of My Innovation is ….

Pre-maturation

Development of a new stereovision system in progress

Università di Corsica Pasquale Paoli

Prospects – Prescribed fires

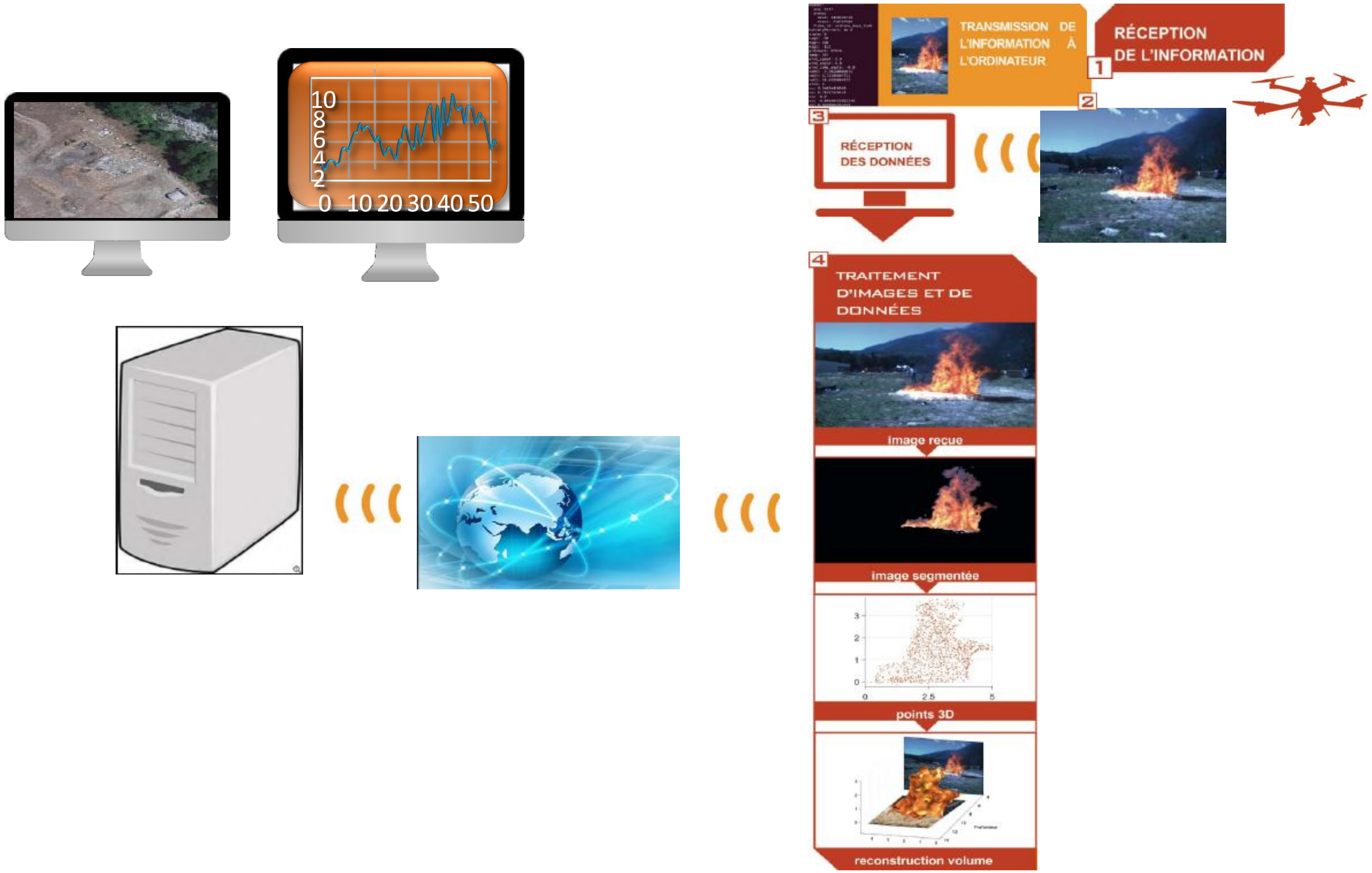
SPE UMR
CNRS 6134

Test of the system on prescribed fires

SPE UMR
CNRS 6134

Prospects – Real time and SIG

Geolocalisation of the geometrical characterictics in real time and display of the data in a web server



Prospects – Data assimilation

SPE UMR
CNRS 6134

Assimilation of the data by the Balbi's behavior fire model in real time

- **Fire Position**
- **Emitted heat flux**

Università di Corsica Pasquale Paoli

Prospects – Autonomous behavior

SPE UMR
CNRS 6134

- **Autonomous drone position for optimal image capture**
- **Tracking of the fire during its propagation**
- **Collaborative work of several drones**

Measurement of wildfire geometrical parameters by drones

SPE UMR
CNRS 6134

Lucile Rossi, Vito Ciullo

UMR CNRS 6134
Sciences Pour l'Environnement
Université de Corse

https://feuxdeforet.universita.corsica

GT UAV, 21 Juin 2019, Marseille