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Measurement of wildfire geometrical parameters by drones

SPE UMR CNRS 6134

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UMR CNRS 6134
Sciences Pour l'Environnement
Université de Corse

https://feuxdeforet.universita.corsica

Garden Workshop 2019, 6 -7 Juin 2019, Toulouse

UMR CNRS 6134 Sciences for the Environment
Forest Fire Project

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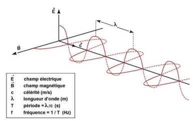
6 research projects

- Water management and recovery in the Mediterranean

- Natural resources

- Renawable energy

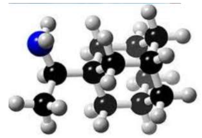
- Information and communication technology



- 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

$$\left.\begin{array}{l} |U_n| > u_0 \tan|\alpha| \Rightarrow \tan\beta = \frac{U_n \cos^2\alpha}{u_0 + U_n \sin\alpha\cos\alpha} \\ |U_n| \leq u_0 \tan|\alpha| \Rightarrow \tan\beta = \frac{\tan\alpha}{1+2\tan^2\alpha} \end{array}\right\} \quad \left.\begin{array}{l} \gamma \leq 0 \Rightarrow r = 1 \\ \gamma > 0 \Rightarrow r\left(1-\frac{1}{\gamma}\right)^3 = A^3(1+\sin\gamma-\cos\gamma)^3 \end{array}\right\}$$

- Development of fire-fighting and land-use tools

https://feuxdeforet.universita.corsica

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Platforms

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Need of experimental data

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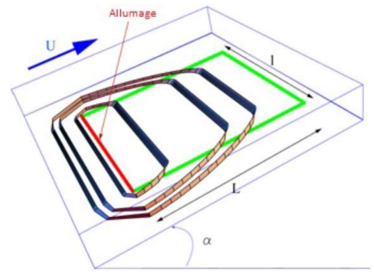
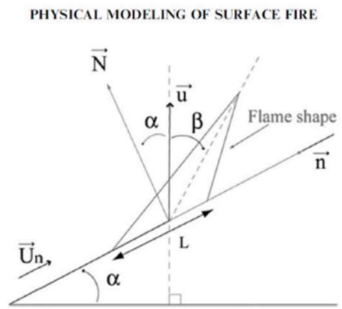
- To understand the phenomena
- To improve or/and validate numerical models



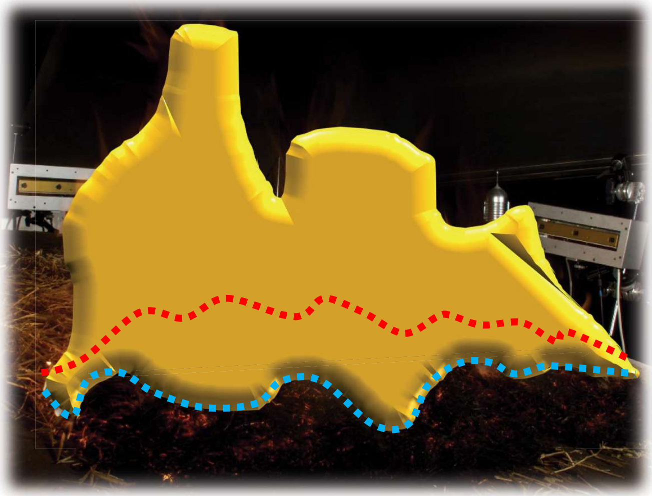
- State of a fire at a given time: its geometrical characteristics



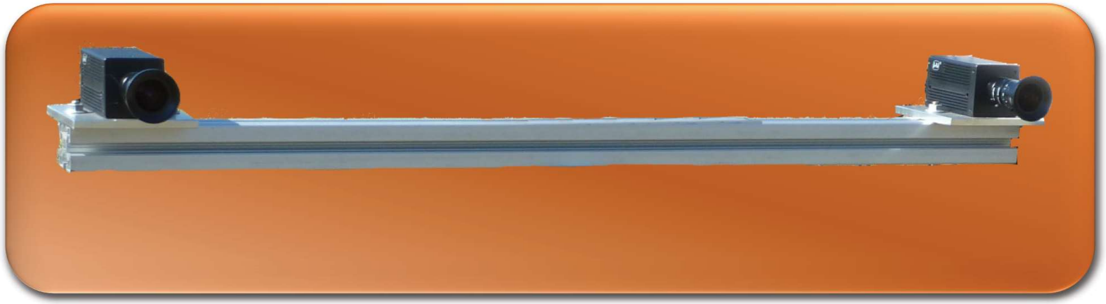
- At several scales: laboratory, semi-field and field

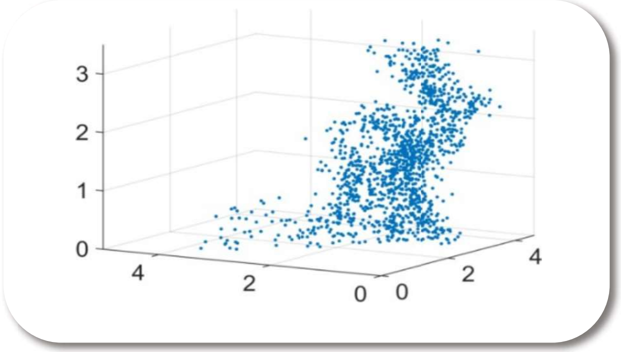
Geometrical characteristics

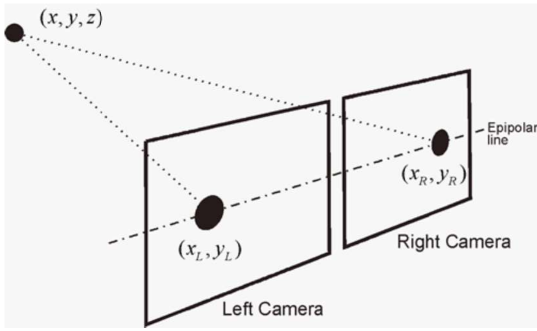
- Position on the ground
- Height
- Length
- Inclination
- Width
- Speed
- Surface
- Volume



3D data obtained by stereovision







Electromagnetic emissions and vision of fire in different spectra

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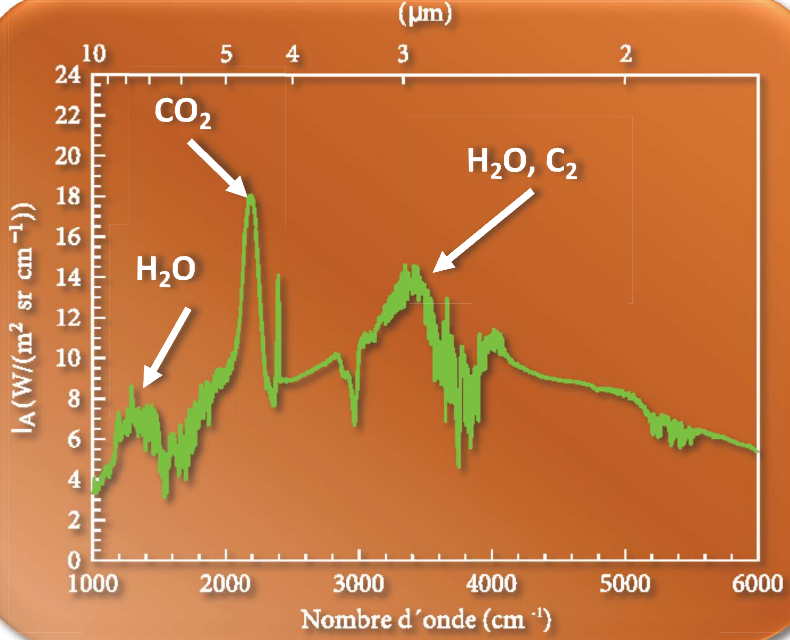
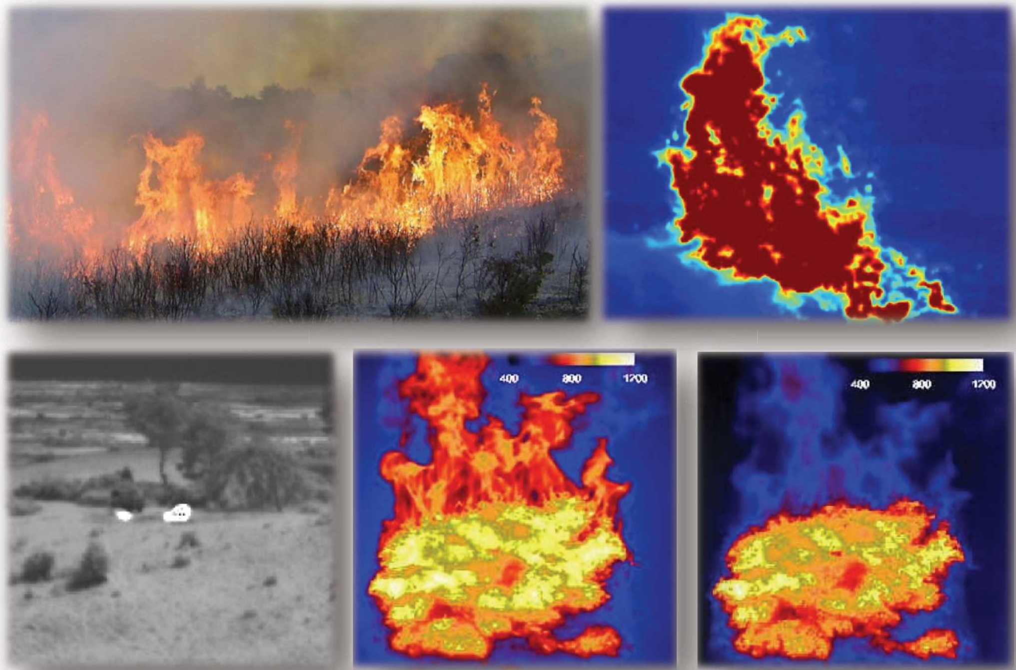
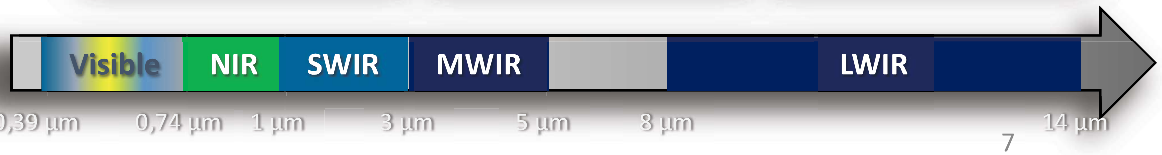
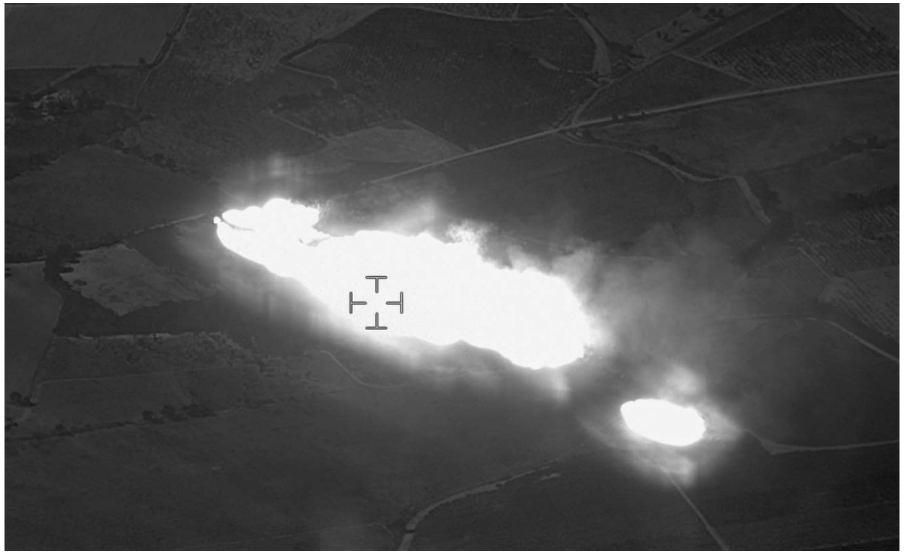
- Combustion process
- High temperatures (400°C to 1500°C)
- Gases : CO_2, H_2O
- Solids : soots, embers, ashes







Images of a spreading fire in the visible and infrared spectra



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Detection of fire pixels in the visible domain

- **Visible domain: reference**

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

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

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Corsican Fire database

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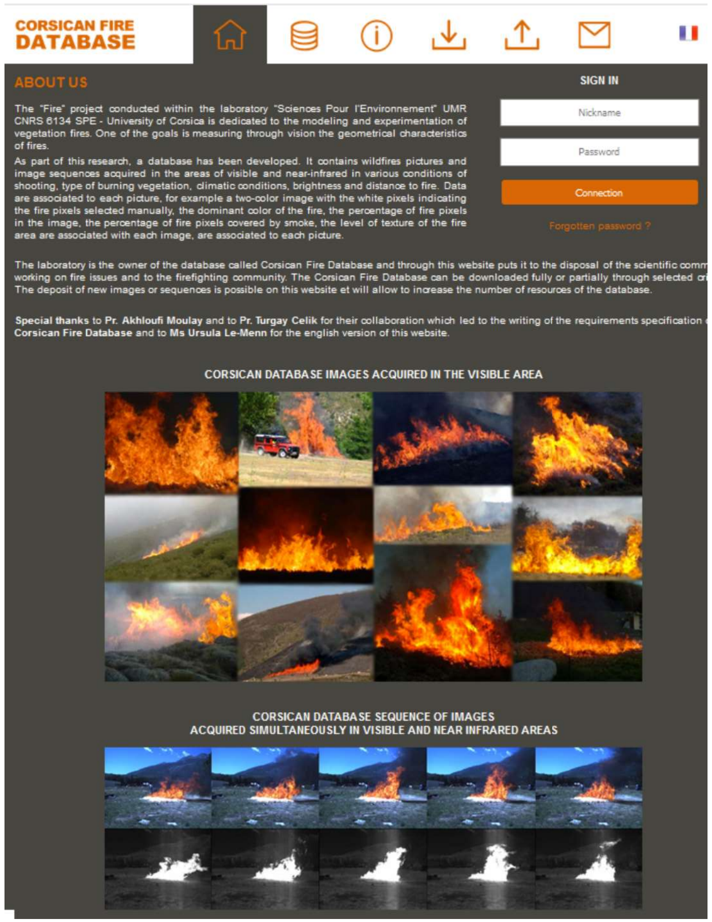
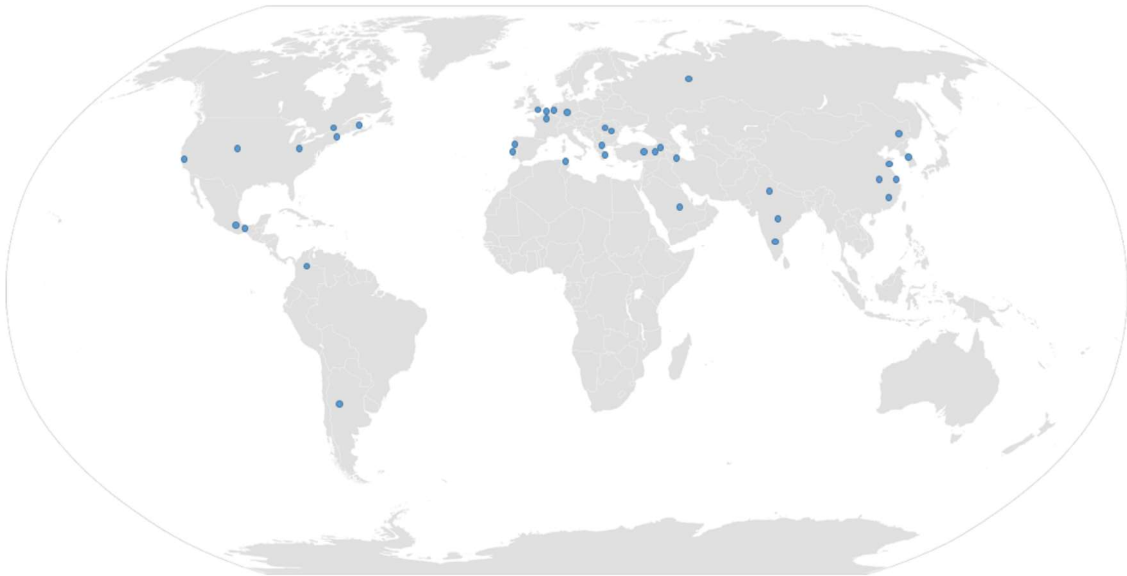


http://cfdb.univ-corse.fr/

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

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Multimodal fire detection by result fusion

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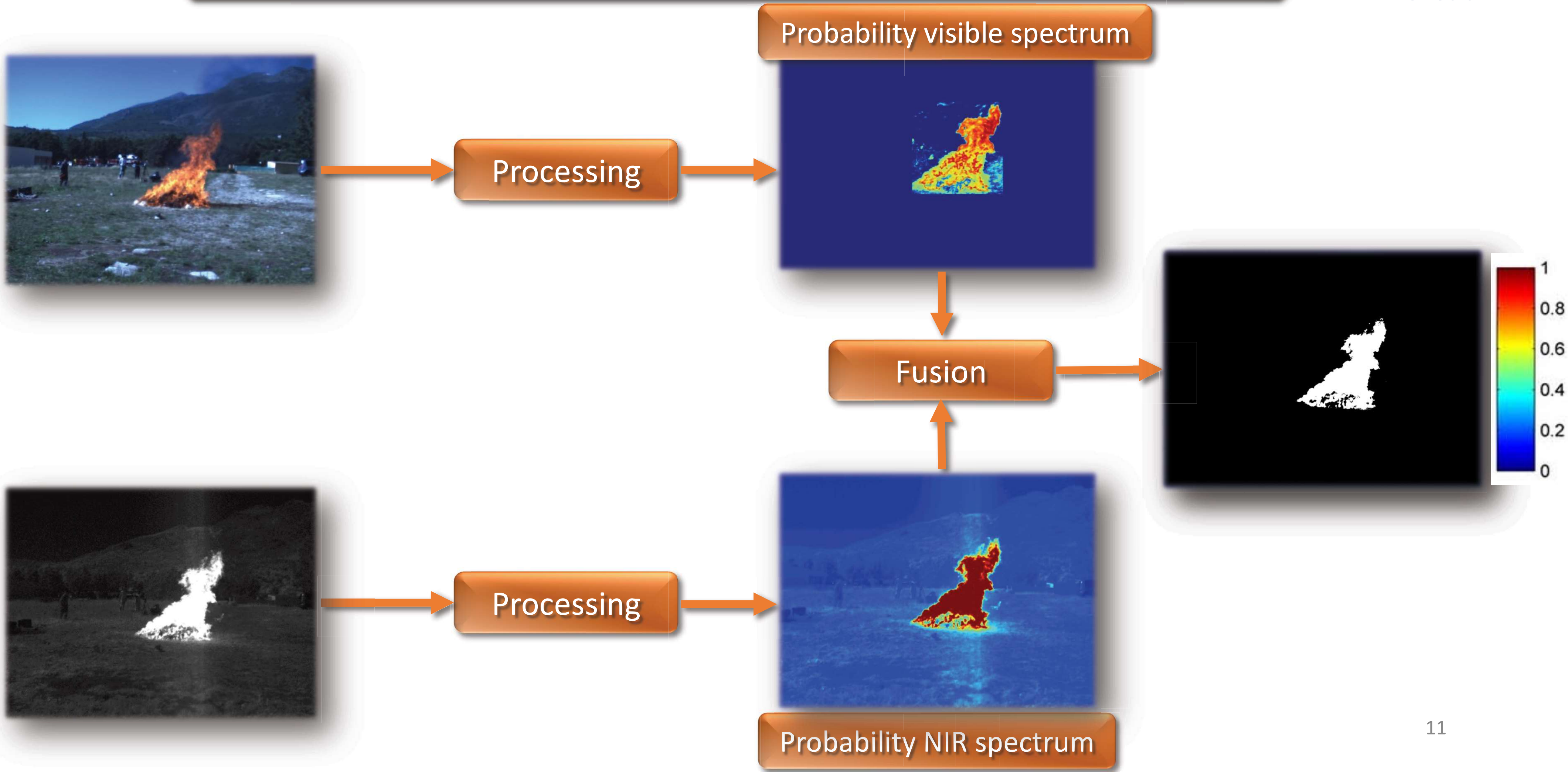
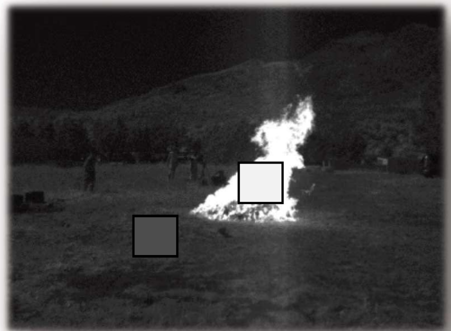


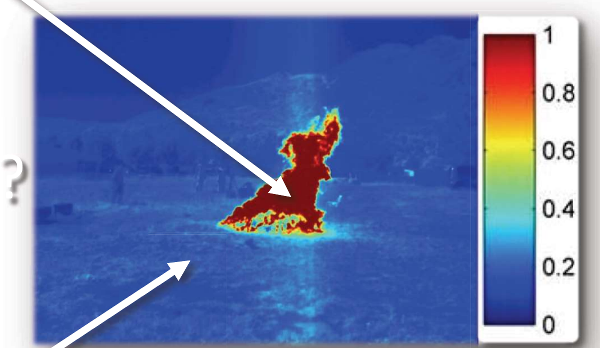
Probability associated to each pixel of an infrared image



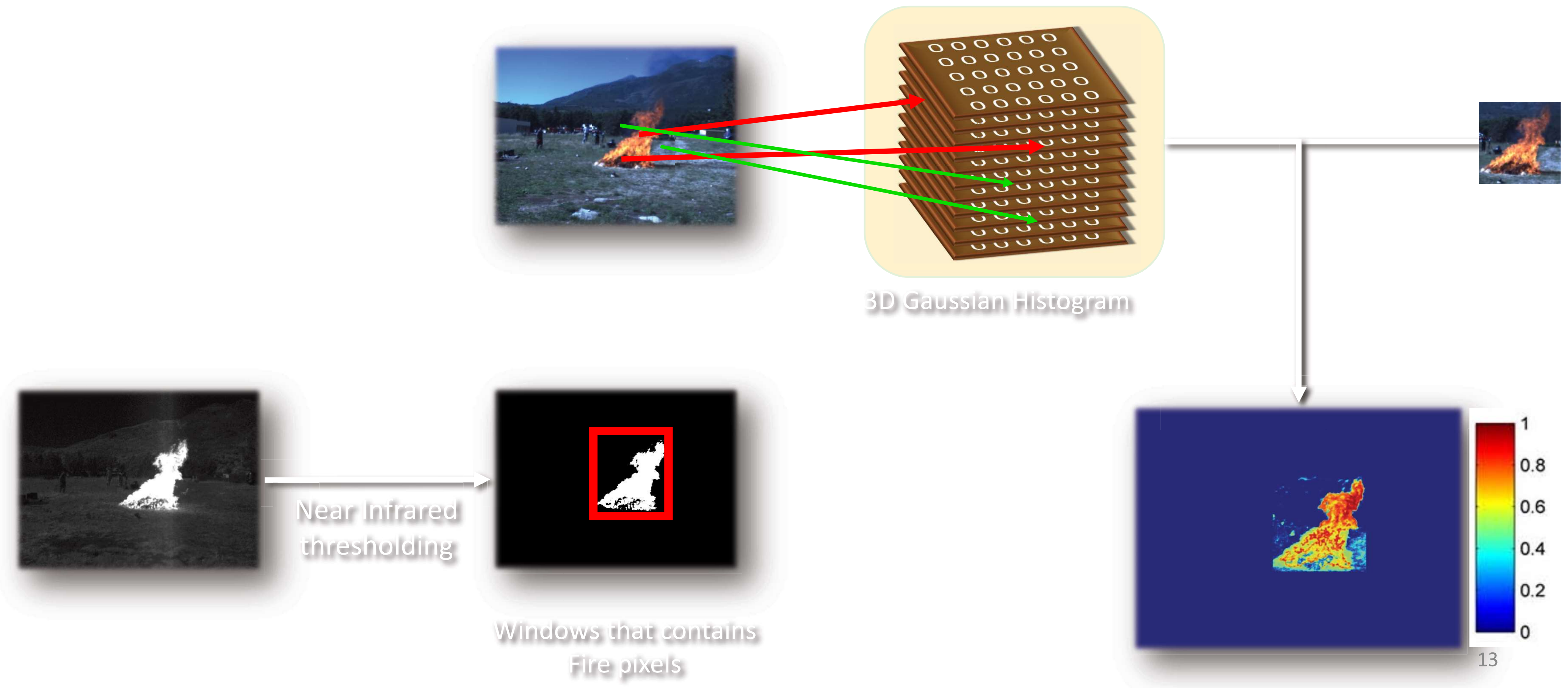
$$p(\mathrm{feu}|x) = \frac{x-t}{2(255-t)} + \frac{1}{2}$$

$$> \text{threshold ?}$$

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



Probability associated to each pixel of a visible image



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Fire measurement by stereovision

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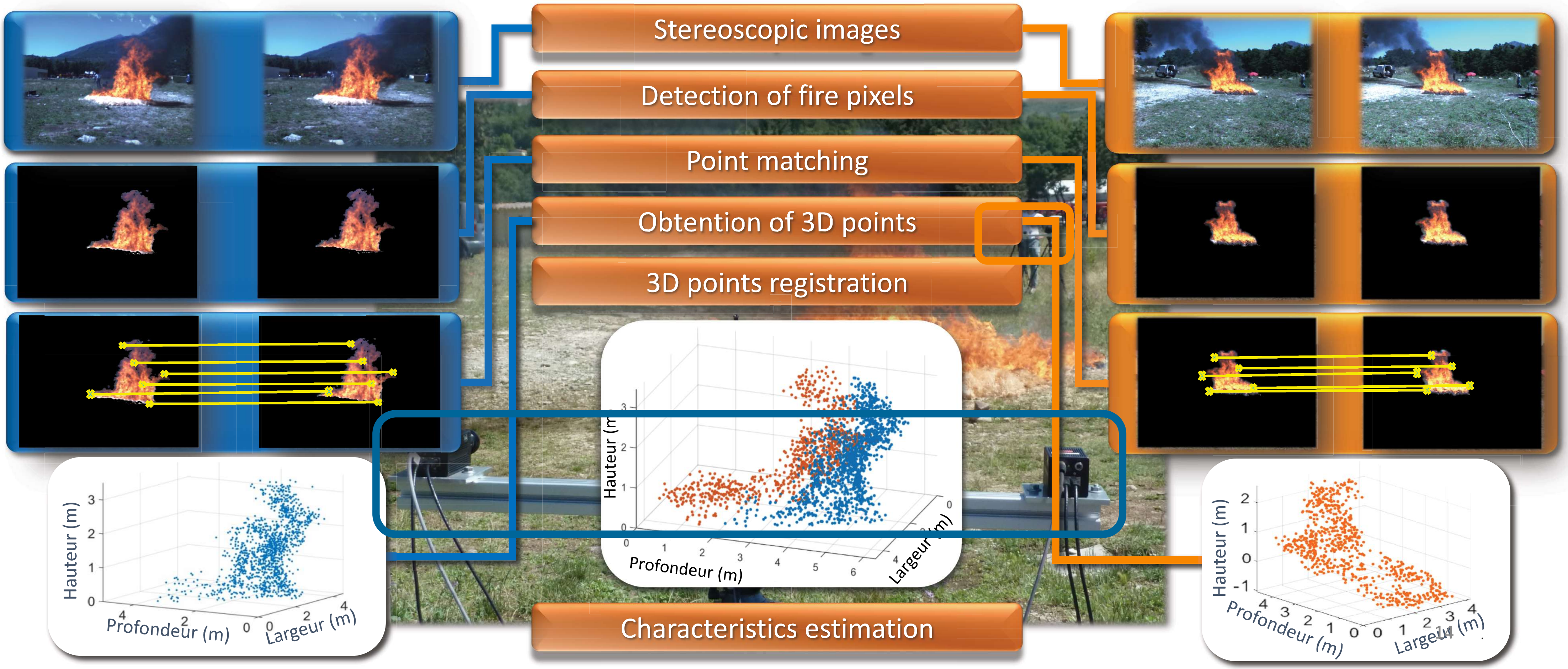

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Registration of 3D points
Obtained from the various stereovision systems

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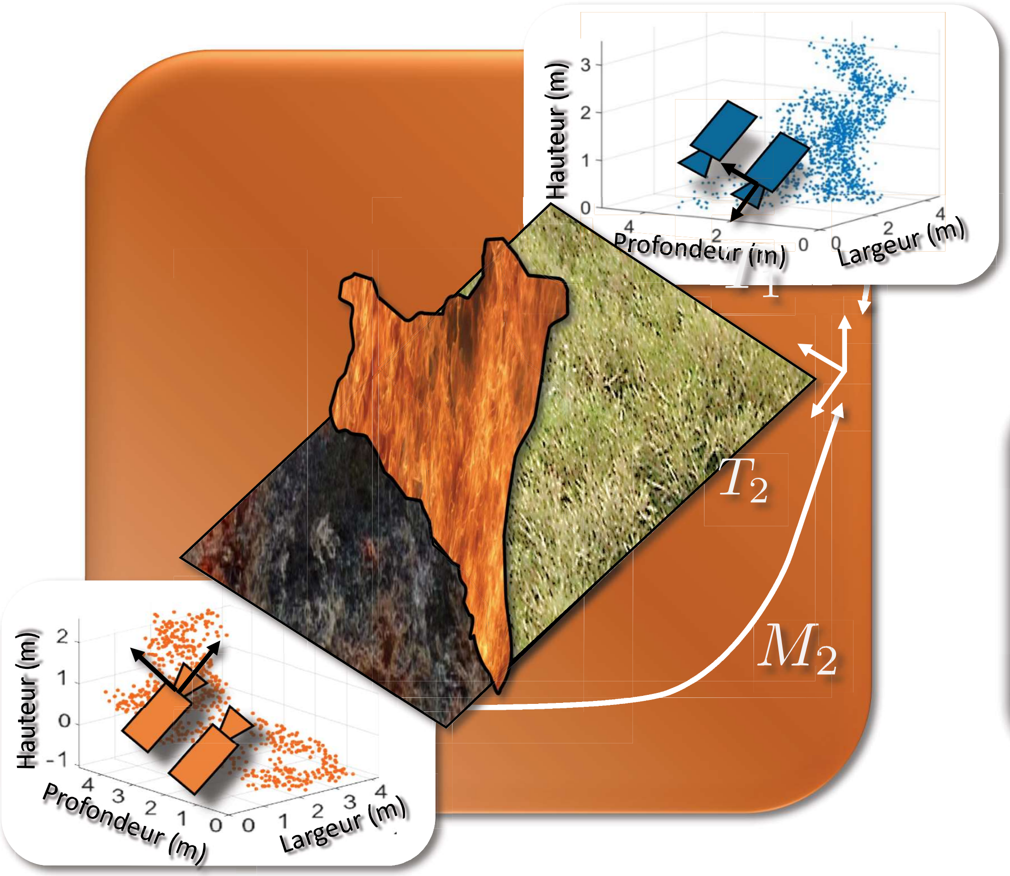
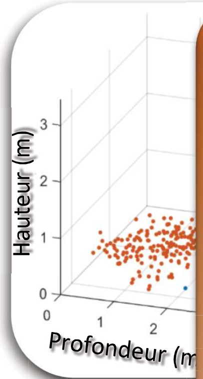


Flight controller of the AR Parrot UAV



GPS Leica Viva CS10 receptor with RTK system

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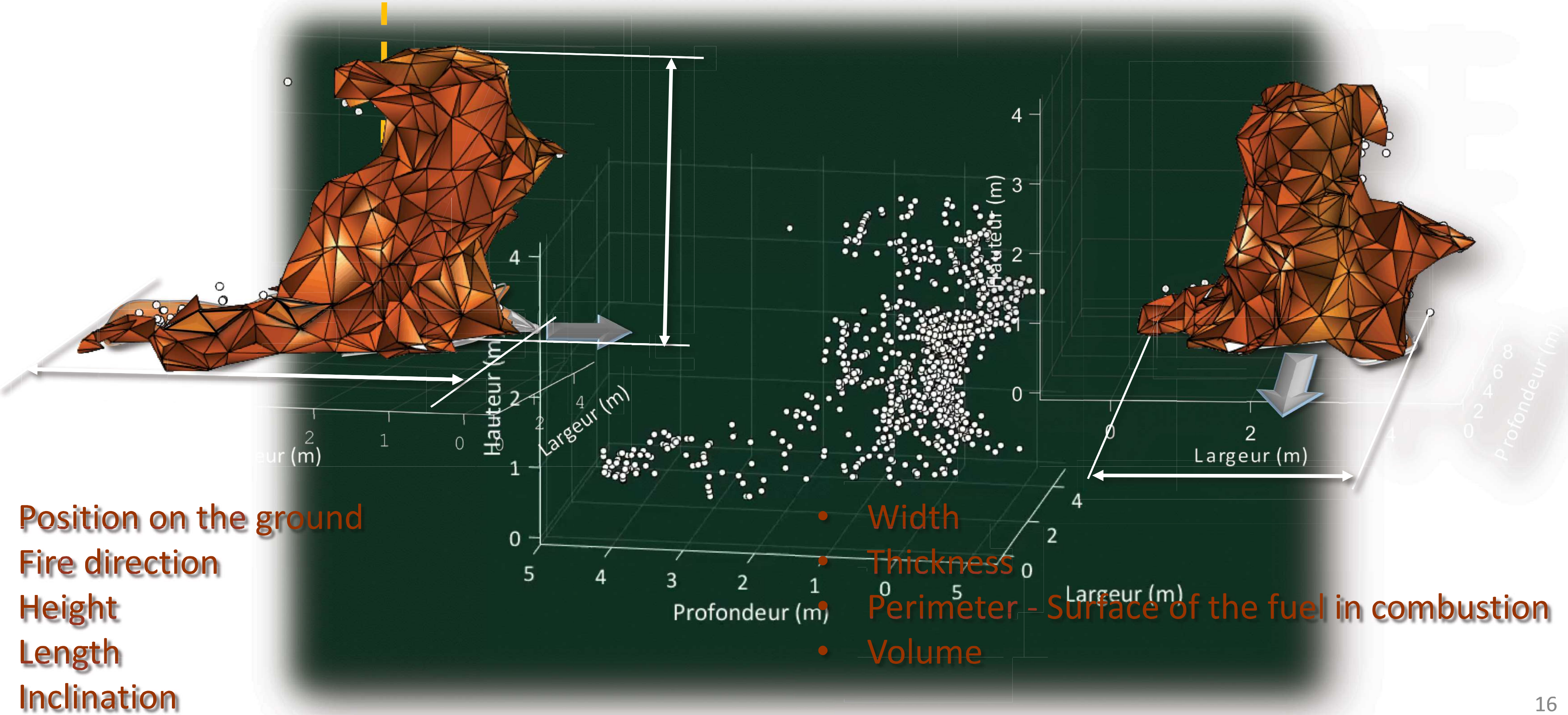
Fire geometrical characteristics estimation



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

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

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Prescribed fires

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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**

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Use of drone to detect and monitor fires

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

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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.**

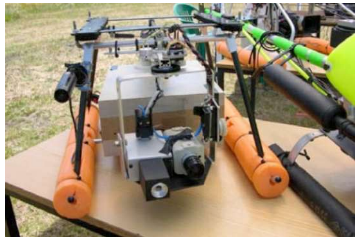
I. Introduction

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



2011

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

Article

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

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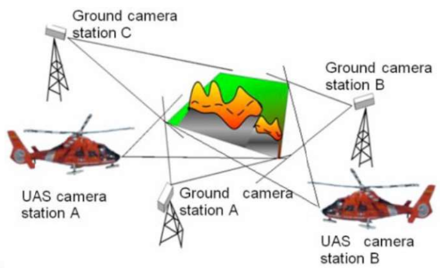
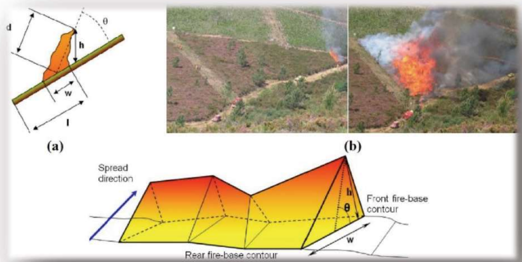
*Received: 1 April 2011; in revised form: 31 May 2011 / Accepted: 2 June 2011 /
Published: 16 June 2011*





2015

NRC Research Press
783
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.

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

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Measurement of wildfire geometrical characteristics by UAV

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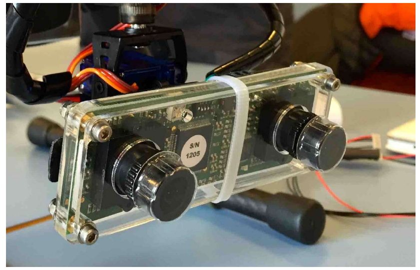
- **Work started in 2015**
- **Continuity of works using stereovision**



- **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 m^2**

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Development of a stereovision system and assembly on drone

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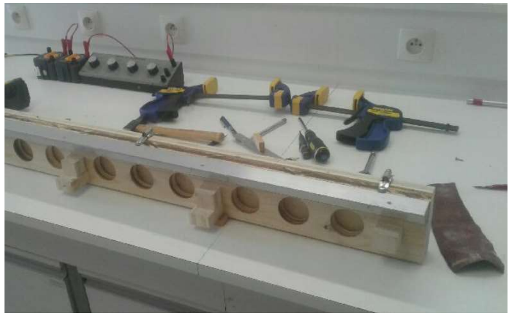
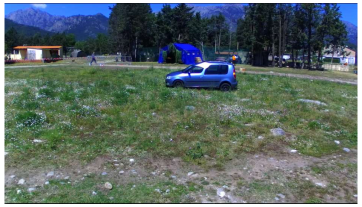


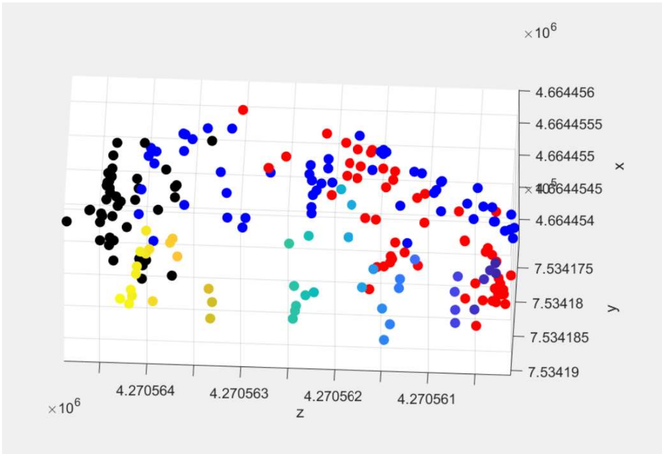
Leopard Imaging camera
LI-OV4689-MIPI
2.8 mm focal length
1280 x 800 pixels
Synchronisation

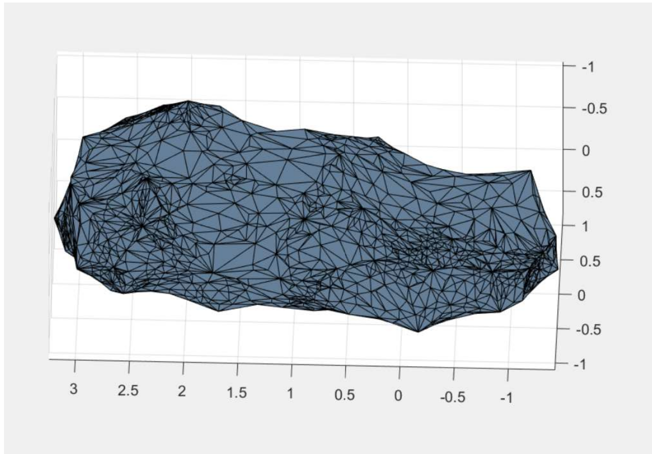
- Baseline = 0.9 m
- Weight = 2.6 kg

Calibration procedure

Ground truth







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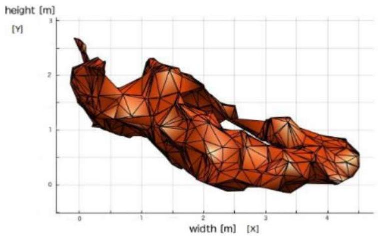
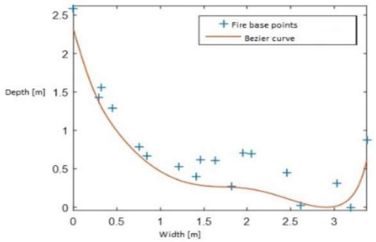
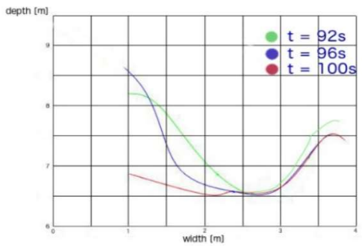
Canonical case

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







Propagating fire experimental setup

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Measurement of propagating fire geometrical characteristics by drone

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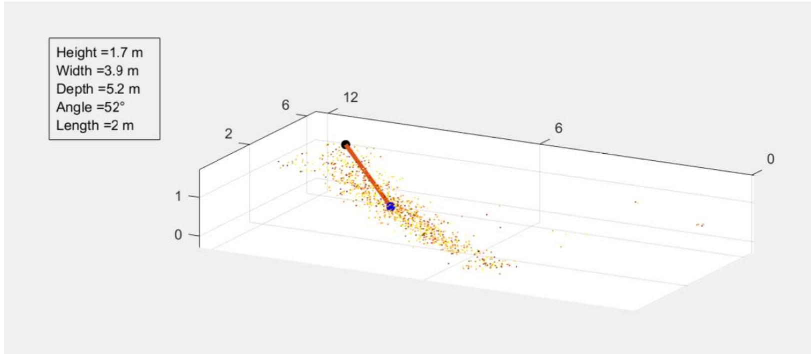

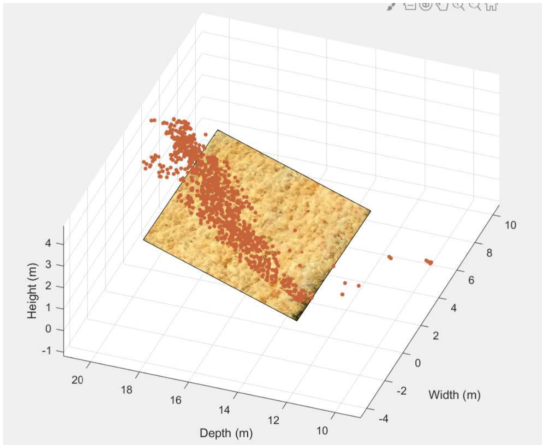

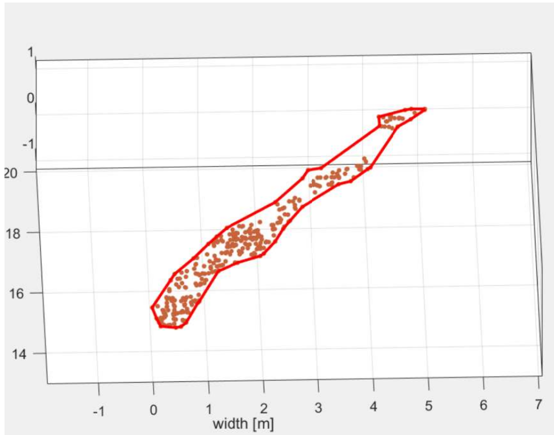

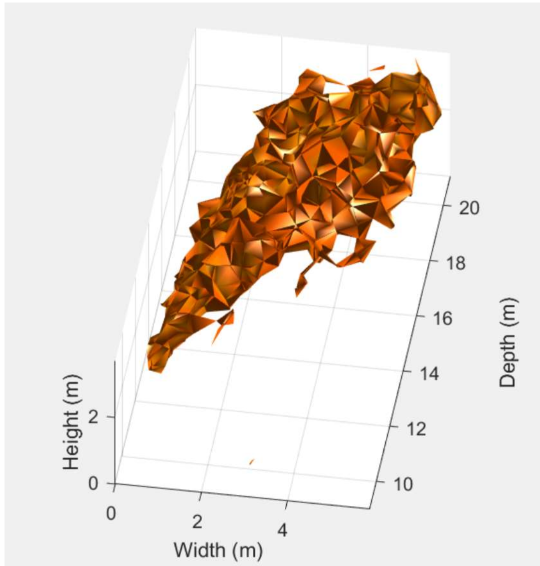

Measurement of geometrical characteristics of a propagating fire by drone

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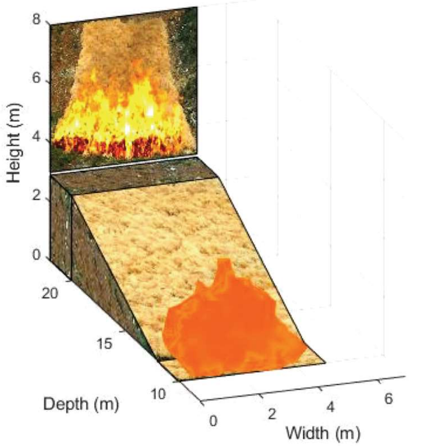
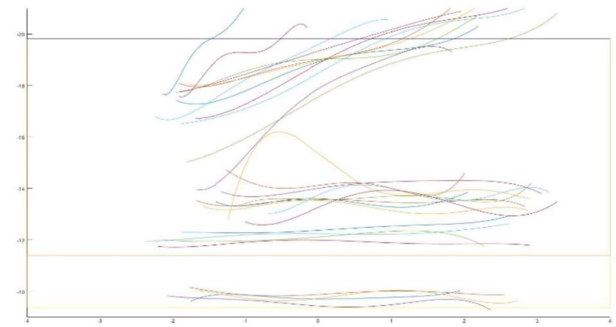
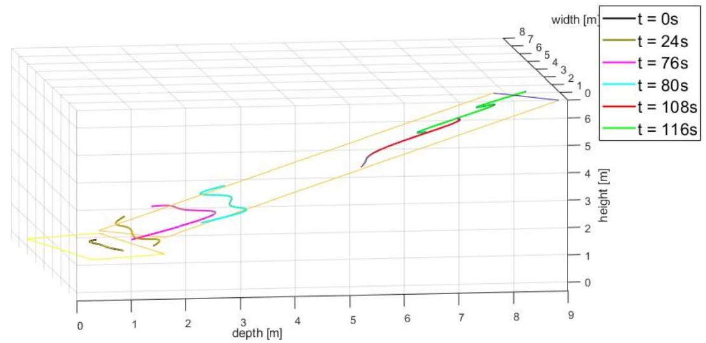


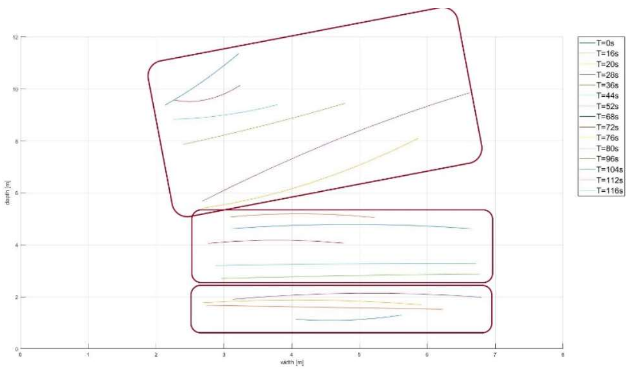
2D Fire front position over time



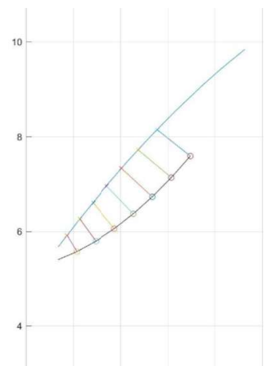
3D Fire front position over time



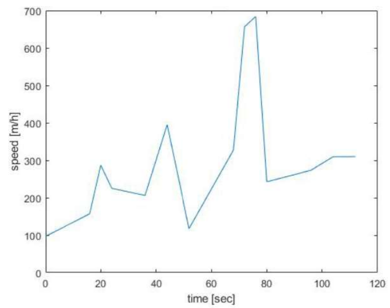
Identification of successive fire spread regimes



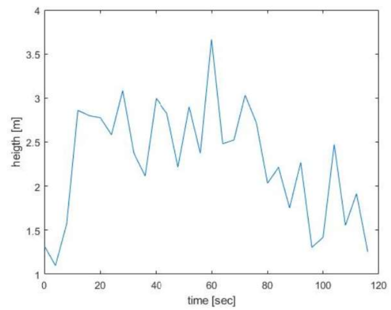
Mean Speed



Speed over time



Heigth over time



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SATT Sud Est
Pre-maturation

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SATT SUD-EST ACCÉLÉRONS LE TRANSFERT DE TECHNOLOGIES

1st Price of My Innovation is ….

↓ **Pre-maturation**

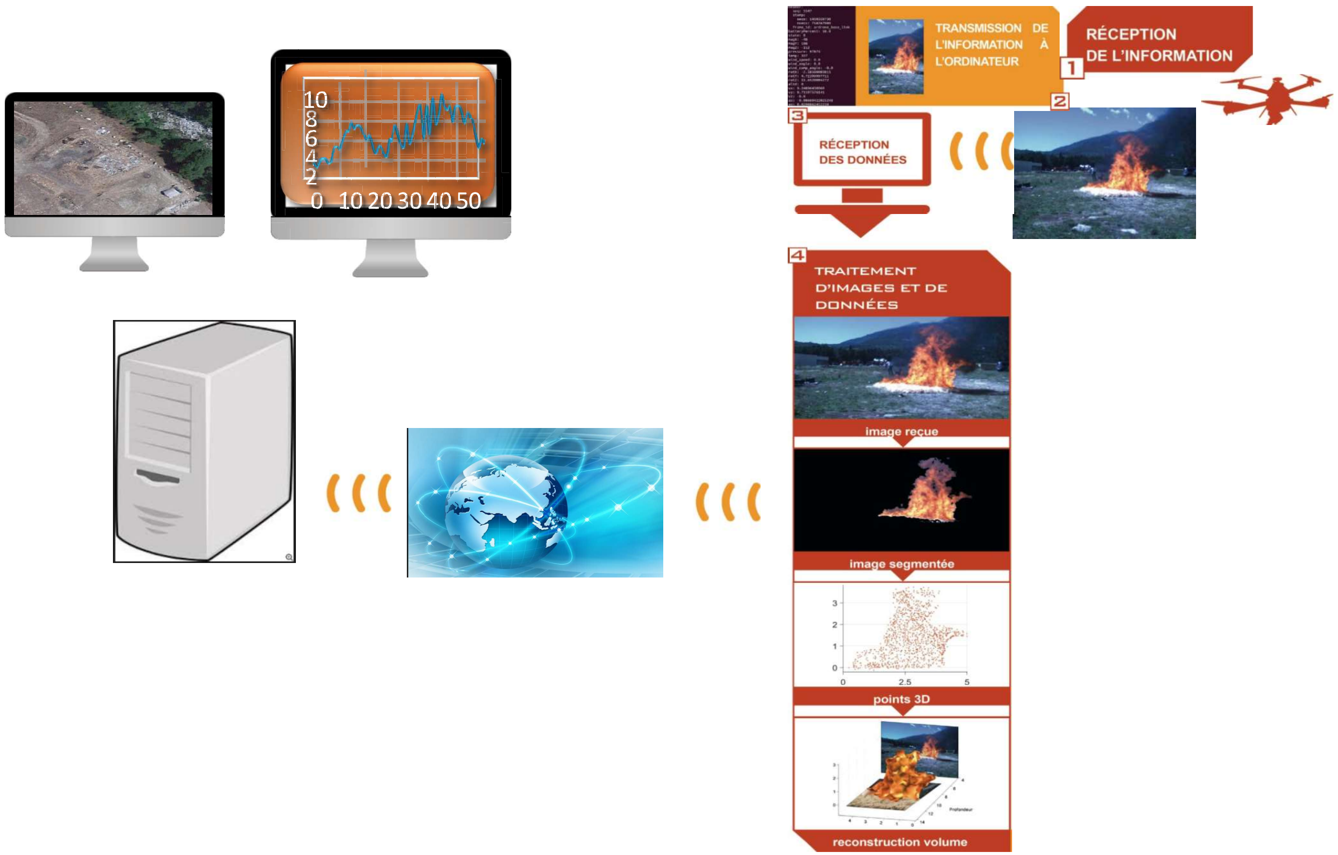
Development of a new stereovision system in progress

Prospects – Prescribed fires

Test of the system on prescribed fires

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

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

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

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Prospects – Autonomous behavior

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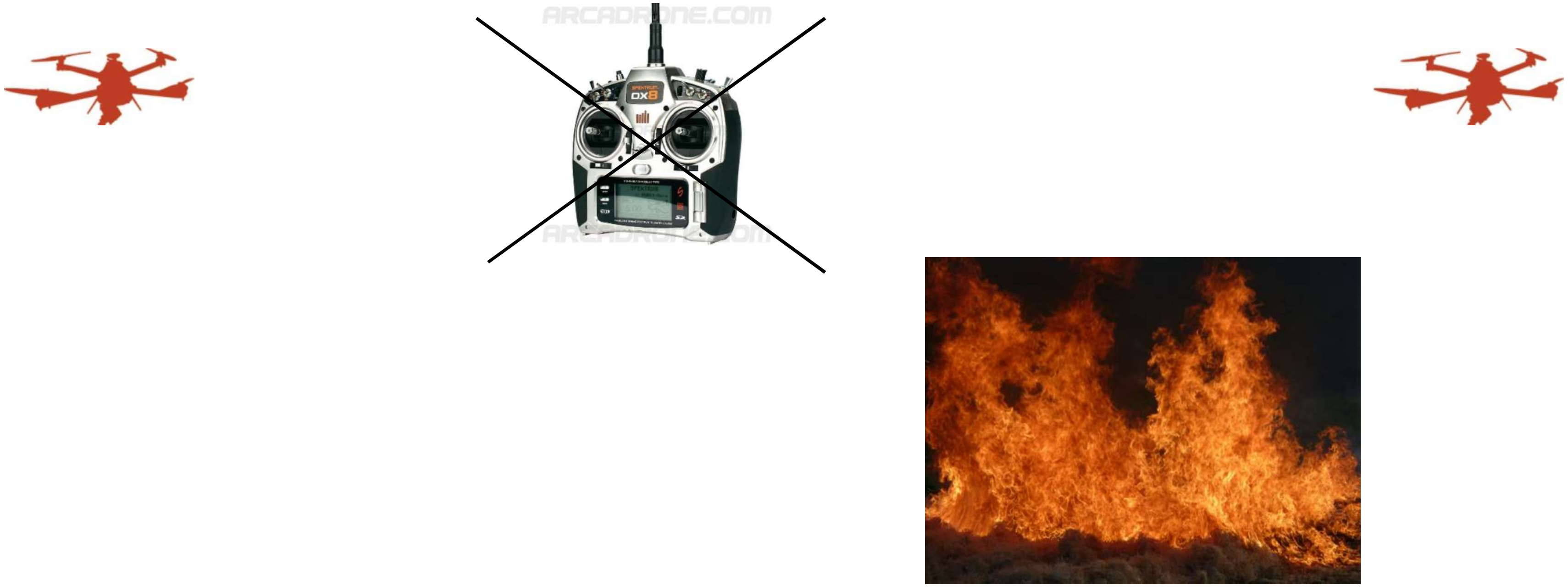
- **Autonomous drone position for optimal image capture**
- **Tracking of the fire during its propagation**
- **Collaborative work of several drones**



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Measurement of wildfire geometrical parameters by drones

SPE UMR CNRS 6134

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Garden Workshop 2019, 6 -7 Juin 2019, Toulouse