CERTEC UPC UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH Centre for Technological Risk Studies

Master Thesis proposal at CERTEC-UPC-BarcelonaTech

SMOKE EVOLUTION MEASUREMENT: ESTIMATION OF 3D SHAPE AND VOLUME OF FIRE PLUMES FROM MULTIPLE VIEWS

Research project general aim

Wildfires are a global phenomena becoming an increasing threat for ecosystems and population entailing fabulous challenges to first responders. To mitigate wildfire effects, operational forecast systems have been developed with either focus at fire scale for application in fire operational attack, or at plume scale for application in air quality. More recently, coupled fire-atmospheres systems (based on atmospheric meso-scale model) have been developed to resolve simultaneously the plume updraft/smoke dispersion, the propagation of the fire front, and their mutual interactions. While still mostly used as research tools, they are intended to become operational. To achieve so, a large amount of effort is being devoted by the scientific community in model testing with experimental data, either coming from laboratory fires, experimental forest fires and real wildfire incidents.

The aim of this research project is to develop a new method to measure wildfire plume dimensions and geometry over 3D space and time by means of computer vision techniques. In comparison with fuel and fire monitoring, smoke remote sensing is significantly less developed, mainly due to the highly dynamic nature of smoke and its very variable optical properties. Advances from the current state of the art are expected in this project to provide significant impact on plume models testing with the final aim of maintaining ecosystems and minimizing smoke impacts in fire management operations.

Beach Fire ignited by lightning near Mono Lake's southeast shore, Northern California (August 2020)

Aim of this Thesis

The main aim of the Thesis is to make a significant contribution towards the **development of a computer-vision-based approach to capture the plume envelop in space and time**, **from multiple synchronized cameras observing the fire plume from different view angles, with the aim of reconstructing the 3D volumes of the plume using stereovision.** Recent advances in image segmentation exploiting deep learning and 3D scene reconstruction will be leveraged to develop a new tool that allows measuring the plume geometry and connecting it with fuel structure, fire dynamics and smoke species emission.

Thesis workplan

This Thesis will be focused in 3D reconstruction of the plume from 2D images, in order to capture 3D volume to be integrated in the plume monitoring methodology. Previous investigation results on 2D smoke segmentation in video sequences applied to field and laboratory fires will be used in this Thesis as baseline.

- **Task 1. Literature analysis of the state-of-the-art approaches for plume reconstruction**: Computer vision techniques will be the technological basis of the research project to reconstruct and track smoke. Since there is at present no clear outperforming methodology for this purpose, a number of state-of-the-art approaches (e.g. Aboud Albadra et al, Determining the three-dimensional structure of a volcanic plume using Unoccupied Aerial System (UAS) imagery (2020) JVolGeoRes 407, doi: 10.1016/ j.jvolgeores.2019.106731) will be investigated. Multispectral data fusion approaches will be explored to take advantage of availability of visible and infrared imagery.
- **Task 2. Laboratory fire tests execution**. To assess and develop the method, a set of experimental fires will be performed at the FlamesLab laboratory at CERTEC combining fuels of different nature (natural fuels such as pine, needles and straw) and different degrees of moisture content. Hydrocarbon fires (e.g. gasoline and diesel) might be also used to test algorithms against the widest palette of smoke texture as possible. A monitoring strategy with multiple synchronized cameras (visible and IR) operating from different view angles will be set for stereovision in plume 3D reconstruction.
- **Task 3. Literature analysis of the state-of-the-art approaches for image registration and stereovision techniques applied to smoke monitoring**. Computer vision techniques will be the technological basis of the research project to visualize the 3D envelope of the plume. Since there is at present no clear outperforming methodology for this purpose, a number of state-of-the-art approaches will be investigated.
- **Task 4. Experimental datasets gathering - smoke segmentation**. Smoke segmentation imagery and data obtained from previous work on experimental laboratory fires, will be gathered and classified. Available algorithms for smoke segmentation will be used to segment smoke from outdoor experimental fires.
- **Task 5. Algorithms testing.** Methods investigated in task 1 will be assessed, compared and eventually combined to perform smoke reconstruction of laboratory fires imagery. A preliminary solution will be implemented to be coupled with image registration and stereovision techniques for a final 3D volume characterization of the plume. For the reconstruction stage, methods investigated in task 3 will also be assessed to perform 3D plume reconstruction of experimental fires. A preliminary solution will be implemented and documented. Upscaling to real fires will be discussed.

Requisites

We seek students with a strong motivation for scientific research, with a strong base of Computer Vision and Deep Learning. The candidate has also to be fluent in English and Spanish, both written and spoken.

Research location: GPI/CERTEC at UPC-BarcelonaTech

The successful candidate will develop this Thesis in a collaboration between GPI (the Image Processing Group, imatge.upc.edu) in Campus Nord (D5) and CERTEC (Center for Technological Risk Studies, certec.upc.es) located at the brand-new Diagonal Besòs Campus.