Cyber-physical systems for wildfire management operations

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CTS – Center of Technology and Systems

Technologies & Techniques
- Electronic & Embedded Systems
- Energy & Decision Systems
- Computer Engineering Systems

Framework levels
- Cognitive collaborative system
- System-of-systems
- Intelligent System
- Smart device / Smart Sensor

Application domains (main)
- Manufacturing
- Energy Systems
- Health & Care
- Space industry
- Transportation, Agribusiness & Smart Cities
Motivation

• Wildfires are a universal problem that affects innumerable areas of the globe with special incidence on countries with warm summers, such as, Portugal, Spain, Greece, Australia and United States of America

• In the past 20 years Portugal has been severely affect by wildfires.
  • In 2017 they has caused a major impact with a high number of life losses and an extensive burnt area (the highest in 20 years)

• Prevention, early detection and more effective fire suppression strategies are essential to change this dramatic tendency

![Burnt area (hectares)](https://pordata.com)
**CTS Areas of Intervention in Wildfire Management**

**Land Cover-Land Use Maps**
- Innovative classification strategies
- Computational Intelligence
- Sentinel-2 Imagery

**Early Fire Detection**
- Rekindle detection
- UAVs and firefighting vehicles equipped with the right sensors

**Smart Sensing**
- Low cost, power efficient, reconfigurable and multifunctional smart sensors
- Flexible wireless sensor network

**Spatial Decision Support Tools**
- Up-to-date knowledge of the landscape
- Advanced visualization interfaces and dashboards
CTS Research Projects in Wildfire Management

CTS is leading several FCT funded research projects:

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Data fusion of sensor networks and fire spread modelling for decision support in forest fire suppression
foRESTER – Project Objectives

• Improve decision making during wildfires crisis to minimize its negative consequences

• Develop a decision support system integrating various sources of information, based on:
  • advanced computational intelligence and visualization techniques;
  • innovative multi-sensor-based technologies;
  • satellite image processing;
  • real-time fire propagation predictions.

• Collaboration with Mação Municipality
Multidisciplinary Consorcium

Hardware design;
Image processing
Multi-criteria decision

Fire Propagation Modeling

Land cover and land use cartography

Weather forecasts

Cartography IPSentinel Platform

Image processing

Pilot Region MacFIRE
Technological Contributions

• At hardware level:
  • Multi-sensor, flexible, reconfigurable, portable and low-cost system
  • Classification of fire front through image processing

• At the Software level:
  • Generation of maps of occupation and land use, using AI techniques
  • Fire Propagation models based on up-to-date terrain data (cartography and meteorology)
  • Decision support system that integrates advanced visualization and multi-source data fusion
Contributions to society

• Provide command centers with useful, up-to-date and solid information.
• Increased efficiency in the management of resource to combat fires.
• Valuation of the MacFIRE Platform.
• Fire Propagation Simulation.
FoCor
Using Unmanned Aerial Vehicles to Assist Prescribed Fires and Detect Rekindles in Wildfire Management
**FoCor - Project Objectives**

- **O1.** Develop and Adapt UAVs platforms fitted to operate in Rekindle and Prescribed Fires operations.
- **O2.** Choose the sensors suited to support Prescribed Fires and Rekindle Detection operations.
- **O3.** Development of Multimodal Perception for Aerial Surveys algorithms to identify biomass and humidity levels, forest gaps, fire perimeters, and hot spots.
- **O4.** UAV Autonomy.
  - Localisation and Mapping;
  - Motion and path planning,;
  - Advanced Navigation and positioning;
  - Implementation of a Health and Diagnostics system
- **O5.** Develop the Mission Platform.
- **O6.** Develop Mission Planning Software.
- **O7.** Safety and regulation.
Heterogenous Robot Swarm: Prevention

Risk Management and Mapping

Multi-Layer Mapping

Prescribed Fire Support

Monitoring

Ignition
Heterogenous Robot Swarm: Rekindle
Post-Fire: Ignition Rekindle Detection

• Monitoring and Detection
  • Onboard Sensors supported by Deep Learning Algorithms allow to identify possible rekindle

• Navigation and Planning
  • Optimized coverage algorithms capable of reacting to online data
  • Capable of operating in harsh enviroments
FUELMON

Semi-automatic Fire Break Maintenance Operations Detection
Fire Break Maintenance Operations Detection

• The Portuguese Institute of Nature and Forest Conservation defined the Fire Breaks Network (11,125Km, 1,600Km already implemented)

• A Fire Break is a strip of land that has been strategically and artificially modified, where vegetation density is reduced to break up the continuity of fuel

• It acts as a barrier to slow or stop the progress of wildfire

• Its maintenance must be ensured and verified periodically
Research Partners

Lead Partner
Computational Intelligence
Image Processing

Participating Institution
Forestry Engineering
Remote Sensing data analysis

End User (collaboration)
Responsible for the implementation and management of fuel Breaks
Technological Contributions

• At the Software Level:
  • Exploration of an intelligent data fusion algorithm for classification of multispectral images
  • Temporal fusion of images to compensate for the presence of clouds and improve classification
  • Evaluation of the use of Sentinel-2 images to study the primary NETWORK FGC (100m wide)
  • Estimation of accumulated biomass using earth observation images after a maintenance operation
Contributions to society

• Supervision of the execution of scheduled maintenance of FGCs
• FGC maintenance planning
• Generation of maps with the estimation of accumulated biomass that can be used to evaluate the effectiveness of FGCs
IPSTERS

IPSentinel Terrestrial Enhanced Recognition System
IPSTERS – Project Objectives

• **IPSsentinel** - Portuguese infrastructure developed by the DGT and IPMA partnership to store and provide images of Sentinel satellites (Copernicus), covering the Portuguese territory and its search and rescue area

**Objectives:**

• Apply AI techniques in the processing of satellite images provided by IPSsentinel for optimized generation of value-added maps (e.g.: ground occupancy maps, level-3 products)

• Produce more regular and updated Land Cover Land Use (LCLU) maps with a reduced legend

• Generation of level-3 maps:
  • Irrigated areas and water bodies;
  • Forest classification;
  • Changes in forest areas;
Research Partners

**Principal Contractor**
AI Techniques
Parallel processing in hardware

**Participating Institution**
AI techniques
Remote Sensing data analysis

**Participating Institution**
Public Administration Entity
Responsible for LCLU national cartography
IPSentinel data provider
Technological Contributions

• At the Software level:
  • Advances in the generation of Land Cover Land Use maps (LCLU) using active learning in the context of "Big Data" in remote sensing
  • Exploration of an intelligent algorithm of data fusion for classification of multispectral images

• At hardware level:
  • Implementation of AI algorithms in dedicated hardware (GPU and FPGA) to accelerate data processing
Contributions to society

- Availability in IPSentinel of data in free and public access, motivating the Public Administration, and other institutions and companies to include the products generated in their workflow.
- Processing on dedicated hardware platforms as a way to reduce energy consumption and reduce product generation time.
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