Forest fire propagation prediction based on overlapping DDDAS forecasts

Tomas Artes, Adrian Cardil, Ana Cortes, Tomas Margalef
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Natural Hazards

MODELING A NATURAL HAZARD

\[ P \]  
\[ P' \]

\[ t_i \]

\[ P' \]

\[ t_i \]

\[ t_i \]

\[ p_1 \quad p_2 \quad p_3 \quad p_4 \quad \ldots \quad p_n \]

Model

Simulator

Prediction \( t_{i+1} \)
Forest Fires: Data sources

- Satellital images
  - Measurement errors
  - Projection distortion
  - Discretization

- Aerial images
  - Measurement errors
  - Discretization

- Weather forecast
  - Prediction errors
  - Models simplification
  - Discretization

- Fire Simulator
  - Model simplification
  - Discretization

- Weather stations
  - Measurement errors
  - Local measures

- Vegetation features
  - Human errors
  - Discretization
  - Measurement errors
  - Time evolution
### Prescribed, Synthetic and Real Fires

<table>
<thead>
<tr>
<th></th>
<th>Synthetic fires</th>
<th>Prescribed fires</th>
<th>Real fires</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fire size</strong></td>
<td>User decision</td>
<td>Hundreds of m²</td>
<td>Hundreds of hectares</td>
</tr>
<tr>
<td><strong>Duration of fire</strong></td>
<td>User decision</td>
<td>Minutes / a few hours</td>
<td>Days</td>
</tr>
<tr>
<td><strong>Conditions</strong></td>
<td>Controlled</td>
<td>Quite controlled</td>
<td>NOT controlled</td>
</tr>
<tr>
<td><strong>Human intervention</strong></td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td><strong>Degree of error</strong></td>
<td>NONE</td>
<td>LOW</td>
<td>HIGH</td>
</tr>
<tr>
<td><strong>Degree of error</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Forest Fire Simulation System (FFSS)

\[ t_x \]

- **Input parameters at** \( t_x \) → **Meteorological model**
- **Wind Sim**
- **Fire Sim**

- **Forecasted parameters at** \( t_x + Dt \) → **Forecasted parameters at** \( t_x + 2Dt \) → **Forecasted parameters at** \( t_x + 3Dt \)
- **Wind Sim**
- **Fire Sim**

- **Real perimeter at** \( t_x \) → **Simulated perimeters at** \( t_{x+1} \)
Forest fire prediction: Methods

**CLASSICAL PREDICTION METHOD**

**INPUTS**

- Static:
  - Elevation
  - Aspect
  - Slope
  - Vegetation
  - Canopy cover
  - Fuel moistures

- Dynamic:
  - Fire perimeters
  - Wind direction
  - Wind speed
  - Temperature
  - Humidity
  - Rainfall

**OUTPUTS**

- Fire perimeters evolution
- Time of arrival
- Fireline intensity
- Flame length
- Rate of spread
- Heat / area
- Reaction intensity
- Crown fire activity
- Spread direction

\[ t_i \rightarrow R_{Ft_i} \rightarrow FFSS \rightarrow S_{Ft_{i+1}} \rightarrow t_{i+1} \]

\[ \varepsilon \]
Forest fire prediction: Methods

### DDDAS PREDICTION METHOD

![Diagram](https://via.placeholder.com/150)

- **Input parameters**
- **FFSS**
- **Simulated fire**
- **Real fire**
- **Parameters Adjustment**

**Parameters Adjustment**

- $t_i$
- $t_{i+1}$
- $t_{i+2}$

**CellsU** - $\cap$

- $\epsilon = \frac{\text{CellsU} - \text{Cells} \cap \text{RealCells} - \text{InitCells}}{\text{RealCells} - \text{InitCells}}$
DDDAS (Genetic Algorithm):

- Real fire perimeter evolution used to calibrate the system

DDDAS (Rate Of Spread- ROS):

- Uses individual points to calibrate the adjustment of maximum rate of spread
Study Case: Cardona Fire

- Cardona fire - Catalonia (northeast of Spain) (lat. 4154 N, long. 1 40 E) during the summer season in 2005, in particular on 8th July.
- The 2005 Cardona Fire burned a total surface of 1439 ha. and it lasted 5 hours.
- The fire started at 14:45 and it keeps burning during 5 hours, until 19:45 approximately.
The forest was used as a test case in this work, took place in Catalonia (northeast of Spain) during the summer season in 2005, in particular on 8th July.

The 2005 Cardona Fire burned a total surface of 1439 ha. and it lasted 5 hours. The fire started at 14:45 and kept burning during 5 hours, until 19:45 approximately.

- Classical Prediction with two different forest fire spread simulators:
  - FARSITE
  - Wildfire Analyst (WFA)
The forest used as a test case in this work, took place in Catalonia (northeast of Spain) during the summer season in 2005, in particular on 8th July. The 2005 Cardona Fire burned a total surface of 1439 ha. and it lasted 5 hours. The re started at 14:45 and it kept burning during 5 hours, until 19:45 approximately.

Study Case: Cardona Fire

- Two different DDDAS approaches for forest fire spread prediction:
  - Genetic Algorithm: DDDAS-GA (using FARSITE)
  - Rate Of Spread: DDDAS-ROS (using WFA)
The forest was used as a test case in this work, took place in Catalonia (northeast of Spain) during the summer season in 2005, in particular on 8th July. The 2005 Cardona Fire burned a total surface of 1439 ha. It lasted 5 hours. The fire started at 14:45 and it kept burning during 5 hours, until 19:45 approximately.

Study Case: Cardona Fire

We can take advantage of both schemes using an overlapping approach.

- Overlapped DDDAS forecasts:
  - Genetic Algorithm: DDDAS-GA (using FARSITE)
  - Rate Of Spread: DDDAS-ROS (using WFA)
EFFIS is a comprehensive system covering the full cycle of forest fire management, from forest fire prevention and preparedness to post-fire damage analysis.

The European Forest Fire Information System (EFFIS) http://forest.jrc.ec.europa.eu/effis/
Forest Fires: Data sources

- **Aerial images**
  - Measurement errors
  - Projection distortion
  - Discretization

- **Satellite images**
  - Measurement errors
  - Discretization

- **Weather forecast**
  - Prediction errors
  - Models simplification
  - Discretization

- **Fire simulator**
  - Fire simulation

- **Weather stations**
  - Measurement errors
  - Local measures

- **Vegetation features**
  - Human errors
  - Discretization
  - Measurement errors
  - Time evolution

**Fire Simulator**

![Fire Simulator](image1)

**Weather stations**

![Weather stations](image2)

**Satellite images**

![Satellite images](image3)

**Weather forecast**

![Weather forecast](image4)

**Vegetation features**

![Vegetation features](image5)
EFFIS: Experimental results

Extracting fire perimeters from Hotspots
Automatic report of active fires including:

- Fire spread prediction
- Wind field and meteorological data related to the prediction
EFFIS: Experimental results
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Reykjavík, Iceland  |  1-3 June, 2015