The Southern African Advanced Fire Information System

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ABSTRACT

This paper concerns the development of the South African Advanced Fire Information System (AFIS). We describe a use case of wildfires causing electricity transmission lines to be adversely affected. This use case provided the rationale for investment into a system for detecting and monitoring wildfires. AFIS functionality is described and we quantify its user acceptance and benefits before discussing ongoing research and implementation efforts to allow AFIS to become a standards-compliant, service-oriented system serving the original use case but re-deployable or re-usable by other organisations for similar or alternative purposes. We end with a view of future work that will potentially allow AFIS to reach a wider audience.

Keywords

Fires, electricity transmission, open-standards

INTRODUCTION

In southern Africa, fire is a crucial process for healthy functioning of ecosystems, yet fires threaten natural systems, infrastructure and life. Spatio-temporal awareness of fire likelihood, occurrence and behaviour is key to appropriate prevention, response and management. This paper focuses on wildfire risk to infrastructure and describes research-in-progress towards opening, improving and extending AFIS.

Electricity transmission lines and fires – a use case

Fire can severely affect the quality of electricity supply along transmission line networks. Fires near transmission lines can cause line faults resulting in short but significant interruptions in power supply, which can have major financial implication for factories running continuous production processes (Vosloo, 2005). Eskom, South Africa's national energy generator and supplier, operates approximately 28 000 kilometres of transmission lines in South Africa, most crossing fire prone biomes. Consequently, large parts of the transmission grid are exposed to wildfires, especially during the dry winter of June-October in the north-east of the country and the hot, dry months November-March in the south-west.

Figure 1. Grassland wildfire near transmission line

Normally, air acts as an isolation medium (due to its dielectric properties) between live conductors and the ground.

Fire conditions may alter the properties of the air as smoke particles fill the space between the ground and transmission line. An electrical discharge my occur, normally referred to as a line fault or flashover.

To prevent spread of fires underneath transmission lines, early fire detection is required to pinpoint the location and possibly information on fire temperature and size. Previously, Eskom line managers depended on local residents for necessary information about fire occurrences and locations.

Eskom and CSIR, a South African research institute, developed an information system during the 2004 fire season to combat this problem of line faults resulting from wildfires. It became the Advanced Fire Information System, based on satellite-borne sensors detecting active fires, which were forwarded as fire alerts to Eskom users, for appropriate actions.

THE ADVANCED FIRE INFORMATION SYSTEM (AFIS)

AFIS had a simple set of tasks: alert users to the existence of fire events near to infrastructure; archive fire events; and allow access to this archive for web-based query and retrieval of fire event information.

AFIS produces a fire detection when a "hotspot" is observed by remote sensing instruments. Hotspots are pixels with a higher black-body temperature relative to neighbouring pixels. The MODIS (Moderate Resolution Imaging Spectroradiometer) instrument on the Aqua and Terra platforms provides hotspot detection at approximately six-hourly intervals at a one hectare scale. The SEVIRI (Spinning Enhanced Visible and Infrared Imager) sensor aboard Meteosat-8 provides a high temporal resolution (fifteen minute) for hotspot detection, with coarse spatial resolution (five hectare). MODIS and SEVIRI specific algorithms are deployed at two ground receiving stations to extract hotspots. Deployment is 'black-box': sensors data arrives, processing occurs and hotspots are generated into text files. Each hotspot record contains positional, time and other attributes (McFerren, Roos and Terhorst, 2007).

Hotspots are processed into SMS alerts and sent to registered end-users; archived into a database; and served over the web into a web fire-mapper where users query the fire archive. In AFIS version 1, software and application code used was proprietary and closed. We believed that AFIS would become sustainable, more useful and more used if we could redevelop the system using open source software and open-standards. Studies indicate that this expectation was not speculative – NASA performed a Return On Investment study confirming that open-standards are a sound mechanism for delivering geospatial content and services over the Internet (Bambacus and Reichardt, 2006).

High Level Description of AFIS Architecture

We consider here the datasets and software tools initially useful in a wildfire risk management system, primarily focused on the described Eskom use case, but hinting at additonal cases.

Datasets

An important design decision in opening AFIS up to the fire community was the use of open standards from the Open Geospatial Consortium (OGC), combined with widely available and familiar base data services, notably Google Maps.

Dataset Name	Dataset Service Type	Dataset Description
Google Terrain, Hybrid, Satellite	Google maps tiles	Background cartography, orientation, terrain
ESKOM Transmission Towers	OGC WMS/WFS	Pylons along Eskom transmission network
Eskom National Lines	OGC WMS/WFS	Eskom transmission network lines
Fire Protection Associations	OGC WMS/WFS	South African Fire Protection Associations
Kruger Burn Blocks	OGC WMS/WFS	Burn Blocks for veld and bush management in the Kruger National Park
MODIS Active Fires Archive	OGC	Long term archive of MODIS Active Fire

	WMS/WFS	Detections from Terra and Aqua. Point dataset/ also polygon dataset available, representing crude approximation of observation size
MODIS Active Fires Last 24 Hours	OGC WMS/WFS	Active fire detections in last 24 hour window onto above archive. Point and polygon datasets
MODIS Active Fires Last 48 Hours	OGC WMS/WFS	Active fire detections in last 48 hour window onto above archive. Point and polygon datasets
MSG Active Fires Archive	OGC WMS/WFS	An archive of SEVIRI Active Fire Detections from the MSG/ Meteosat-8 Satellite. Point dataset/ also polygon dataset available, representing crude approximation of observation size
MSG Active Fires Last 24 Hours	OGC WMS/WFS	Active fire detections in last 24 hour window onto above archive. Point and polygon datasets
MSG Active Fires Last 48 Hours	OGC WMS/WFS	Active fire detections in last 48 hour window onto above archive. Point and polygon datasets
South Africa Protected Areas	OGC WMS/WFS	South African Protected Areas of various kinds, curated by South African National Biodiversity Institute
Wind speed and direction	OGC WMS/WFS	Wind conditions last observed and reported by WeatherSA's automatic weather stations network, updated hourly in some cases.

Table 1. AFIS datasets

Remote sensing data remains at the heart of AFIS. MODIS aboard Terra and Aqua, and SEVIRI, aboard Meteosat-8 are used for active fires detection.

The CSIR operates two MODIS Direct Broadcast receiving stations, from the Satellite Application Centre (SAC) outside Johannesburg and a station at CSIR in Pretoria operated by Meraka Institute. These stations, located 70 km apart, and connected on a 1 Gbit network, allow some redundancy. Both stations make use of the in-house, largely open source “Sediba” MODIS processing system.

MODIS data products are generated from modified MOD/MYD 14 collection 5 code. Threshold tests were altered to enable detection of smaller, cooler fires within Southern Africa, which can as readily be the cause of a flashover as larger, hotter fires. Daytime channel 21 thresholds have been reduced to 305º K while nighttime thresholds have been reduced to 295º K. Similarly the channel 21–31 difference has been reduced to 7º K from 10º K default. Additional to threshold changes, a false detection mask was built into the algorithm to exclude large, heat-emitting industrial plants.

MSG SEVIRI fire monitoring algorithms typically use some combination of measured brightness temperatures in channels IR3.9 and IR10.8, and the differences between (e.g. standard deviation over an n x n pixel array). The main active fires signal is an increase of observed brightness temperature in channel IR3.9, compared to ambient temperature of the neighbouring pixels. Measurements in channel IR3.9 can be attenuated or enhanced by CO2 and water vapour absorption, solar reflectance during day, and sub-pixel clouds over hot surfaces. We utilise a CSIR algorithm that we are comparing to the EUMETSAT and LandSAF algorithms.

Software

OGC open service interfaces are apparent in AFIS, dominated by the Web Feature Service and the Web Map Service standards for vector data and map portrayals respectively. These services are generated from a Geoserver (http://geoserver.org) instance running within an Apache Tomcat (http://tomcat.apache.org) servlet container on

Linux. Data are stored in the PostgreSQL RDBMS (http://www.postgresql.org) with PostGIS spatial extension (http://postgis.refractions.net) enabled.

Data are fed into the database by a data-feeder workflow. Data from remote sensing processing chains and weather feeds arrive on FTP folders as text files, events listened for by the data-feeder code, written in Python (http://www.python.org). Text files are processed appropriately to extract individual fires or weather stations, which are prepared for loading into the database.

The architecture, described in Figure 2, provides an extensible framework for serving fire risk data services for consumption by numerous clients. The fire web mapper client that collates these datasets is viewable at http://afis.meraka.org.za/afis. It is a javascript application incorporating the open-source OpenLayers library (http://www.openlayers.org). The same data can be displayed in Google Earth or any OGC services capable client and is downloadable from the OGC interfaces in raw formats, such as shapefiles, to allow offline usage and analysis by, for example, Disaster Management authorities.

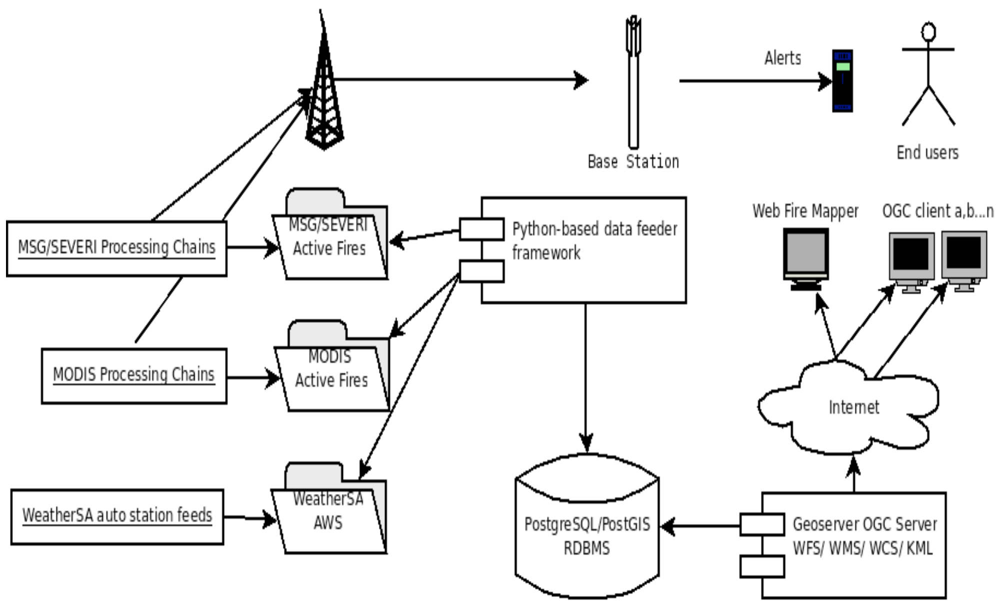

Figure 2. High Level AFIS architecture

AFIS Usage and Acceptance

AFIS has achieved reasonably widespread usage. AFIS has become an integral part of Eskom's transmission line monitoring and management system providing staff with an estimated 5000 alert messages per month during peak fire season. Eskom has reported that flashovers have been prevented by early fire detection numerous times. In one notable jurisdiction, access to the SMS fire alerts resulted in more than 35 cases during two fire seasons (2005 and 2006) where outages were prevented. Eskom enumerates three areas where AFIS has impacted in management of fire risk:

1. Improved management of flashovers
   - Grid managers reported a reduction in flashovers, attributed to awareness generated by fire alerts
2. Better overview of fires
   - Increased awareness of the number and patterns of fires in given areas
   - Locational awareness allowed managers to contact landowners to confirm the nature of fires and

whether fires were under control.

- Monitoring of response – managers could ascertain if fieldworkers responded to fires.

3. Increased planning decision-support for vegetation management near transmission lines.
    - The archive of fires allows the effectiveness and timing of Eskom's vegetation management programme to be analysed and improved.

Outside the original use case, fire alerts are provided to the National Working on Fire program and regional Fire Protection Associations (typically consisting of farmers and fire brigades), thereby supporting response to active fires. MODIS active fire maps have been displayed on national television weather reports.

ADVANCING AFIS

The AFIS system described incorporates research into the use of open-source and open-standards compliant systems, and feedback has been positive. This represents only the first phase of positioning AFIS as a rich platform for delivering wildfire risk information.

Extending use cases

Forthcoming effort will be in researching new use cases and extending the geographic footprint of AFIS. We envisage AFIS being utilised wherever fire threatens infrastructure. An important priority is the positioning of AFIS as a system for assisting in fire monitoring in protected areas. Here, fire management is key to ensuring preservation of ecosystem health, so fire managers require awareness of fire patterns, active fires and burnt areas. Some initial datasets in the current AFIS support this putative use case. An implication of extending AFIS into the ecological management domain is that the archives in particular will be used increasingly as a research platform. This may necessitate effort in understanding how scientists would use the data. One promising approach involves utilising scientific workflows, which automate complex research processes and provide integrated access to datasets that are often large and in potentially distributed locations (Gil, Deelman, Ellisman, Fahringer, Fox, Gannon, Goble, Livny, Moreau and Myers, 2007). Scientific workflows also support reproducibility of experiments and knowledge sharing.

Additional or enhanced products

We consider datasets that become available, and how they could be extended, reduced or combined with other datasets to generate new fire risk products. In coming months we will investigate implementation of a Flashover Probability Index (FPI). This index is important for the Eskom case, as AFIS currently generates too many alerts about fires that do not cause flashovers. Evidence suggests only 2-4 percent of fires near transmission lines result in flashovers (Vosloo, 2005). If fire alerts were to be contextualised with FPI, managers would be able to focus resources more effectively. This FPI would merge remotely sensed fire data with numerical predictions about atmospheric conditions.

We intend to widen the number of fire related datasets as they become available. We expect to provide burnt area datasets, enhanced coverage of automatic weather stations and products relating to Fire Danger Index. Increasing use cases will necessitate more contextual datasets to be served, and it is likely we will consider research into producing rich, customisable and contextual alerts to new users in a scalable fashion.

SUMMARY

AFIS has moved through various iterations and is now poised to become an important contributor to operational fire risk management and research into fire risk. The use of open-standards and open-source software provides good scope for achieving this growth, as cost barriers and interoperability barriers are reduced.

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