

# The Development of a Real-time Wildfire Monitoring and Modeling System

by Landra Trevis and Naser El-Sheimy

## Introduction

Using models to predict fire behaviour has gained much popularity since the advent of Byram's fire intensity equation in 1959 and Rothermel's fire spread model in 1972 (Van Wagner, 1987; Rothermel, 1972). These equations relating fuel, topography and weather to fire behaviour have paved the way for computer-based wildfire propagation models and still remain the cornerstones of today's fire models. BEHAVE (Grabner, 1999), FARSITE (Finney, 1998), FireLib (Bevins, 1996), and Prometheus (Prometheus, 2003) are just a handful of wildfire modeling applications that use the concepts developed by Byram or Rothermel. Now, with our foot in the door of the 21<sup>st</sup> century, we are entering a new era in geomatics technology and wildfire modeling. We enter the era of real-time mapping and Internet applications.

## Motivation

In this era, a new need is developing. Wildfire managers are consistently depending upon their fire modeling systems to estimate situations such as where a fire will spread, what effects adding certain fuel breaks will have, and how fire behaviour will change if weather parameters shift. Despite these abilities, current fire modeling applications are not linked to communications between the spotter aircrafts and the land-based fire management districts. Communications between these two facets are usually done by radio which causes a number of problems. First, during times of severe fire conditions the radio network can become overloaded and no communication will get through to the base station (Wright, 2003). Second, usually only the location and rough size of the fire is reported by radio since it is difficult to verbally report on exact size and propagation details (El-Sheimy and Wright, 2004). Third, hot spot identification during the mop up and post suppression activities are not automated into a computer based detection system and is usually done using crew who scope out the site by hand.

In Alberta, Canada, the University of Calgary has jumped on these inefficiencies and turned them into an opportunity to develop a real-time, Internet-based Wildfire Modeling and Management System (WMMS) prototype to influence the way wildfires are monitored in future years.

## System Components

The WMMS system can be broken down into three components:

- Data Acquisition System (DAS)
- Control Center System (CCS)
- Response System (RS).

The DAS is a system designed by The Mobile Multi-sensor Research Group at the University of Calgary to revolutionize fire hotspot detection (El-Sheimy and Wright, 2004; Wright, 2003). This system is mounted on spotter aircrafts and integrates imaging sensors (Thermal Infrared and RGB Cameras) with attitude determination (inertial navigation system) and location (Wide Area Differential GPS) technologies. It is capable of identifying and uploading the coordinates of

hotspots and fires with 4-5 meter accuracy. For more detailed information on this system refer to Wright and El-Sheimy, 2003.

The Control Center System is the heart of the WMMS system and is actualized by a website application. Through the website, the Control Center System is responsible for organizing and displaying the data collected from the Data Acquisition System, managing fire database information, and housing the fire modeling application.

The final component of this WMMS system is the Response System. This system enables the results calculated by the Control Acquisition System to be displayed to the system user.

## Web Page Design

The WMMS web page was created using the following:

- Apache Web Server
- Web MapServer
- Hypertext Preprocessor Server (PHP)
- Database Server
- Transmission Control Protocol and Internet Protocol (TCP/IP).

### Apache Web Server

The Apache Web Server acts as the computer platform for the system. Its role is to host the Web MapServer and PHP server. Clients can connect to the Apache Web Server from their personal computers. Using the Apache Web Server they can access map data and textual data stored in the WMMS system through the hosted Web MapServer and PHP server.

### Web MapServer

Web MapServer is available free of charge from the University of Minnesota. This public domain server is used for displaying the spatial elements of the WMMS system. One of the pleasing attributes of this server is that it will work on all Linux/Apache, UNIX, and Windows platforms. Web MapServer enables clients to brows GIS data and to manipulate map data by adding or subtracting layers of information.

### PHP Server

PHP is the general purpose scripting language that has been used in conjunction with HTML script to create the WMMS webpage. It was chosen for its ease of use and ability to be imbedded in HTML when developing webpages. Transfer of any image or textual data between the Apache WebServer and client is made possible by the abilities of this scripting language. The language is also efficient enough that users can attain stored spatial and textual data from the WMMS database with little processing and uploading time.

### Database Server

The Standard Query Language (SQL) has been chosen for the database server in this website. It was chosen for its ease of use and for its ability to be upgraded to a more powerful query language. Upgrading would only need to be done if the database expands beyond the capabilities of SQL.

*continued on page 12*

continued from page 11

## TCP/IP Protocol

TCP/IP protocol is the communication protocol that is used for linking the WMMS server to the client's computer over an Internet connection. This protocol works like a mailing system in which packages of data are sent to another computer using destination IP addresses. Using this IP addressing system two computers can share data.

## WMMS Interface

When a client first enters the WMMS site, they will be asked to enter a user name and password. This information is stored by the system's database to monitor the number of people that use the site. Upon a user's first entry to the site, they will be given the status of "general user". There are no restrictions on who can be a general user, and any member of the public can enter the site in this manner. A second class of user can also use the site. This user is called a "managerial user" and is given extra leeway on certain functions that are available in the WMMS system. The only way that an existing general user can be upgraded to a managerial user is if another user with managerial status promotes the user in question. Existing managers can also demote or erase users from the system.

After the login process is complete, the main page of the website is displayed with a map of Alberta centered on the screen. To the left of the centered map is the legend. The WMMS toolbars are displayed to the right. The screen is shown in Figure 1 below and can be accessed from the following Internet address:

[http://cfei.geomatics.ucalgary.ca/FirePub\\_com/firepub.php](http://cfei.geomatics.ucalgary.ca/FirePub_com/firepub.php)

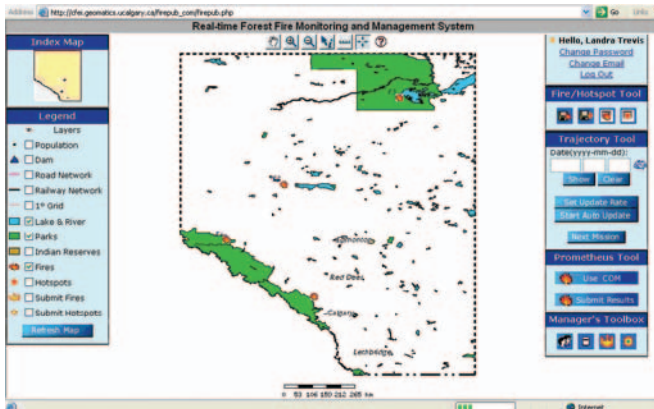


Figure 1: Real-time Wildfire Monitoring and Management System.

Using the legend, the user can add or remove different layers from the main map. Figure 1 shows the web site with the lakes and rivers, parks and fires layers turned on. Looking at the right hand side of the screen the user can see a list of four tools:

- Fire/Hotspot Tool
- Trajectory Tool
- Prometheus Tool
- Managers Toolbox.

## WMMS Tools

### Fire/Hotspot Tool

This tool is where the user can find the uploaded data from the Data Acquisition System. Using this tool the client can manually upload new fires, upload new hotspots, browse historical fire summary reports, and view real-time information on currently burning fires. When accessing the fire summary reports, the user can click on the desired year and see more detailed information about the fires that burned though the province of Alberta. All fires entered into the system are categorized by fire management district. If a user is interested, they can then select the "Active Fires" button and view the latest real-time information uploaded by the Data Acquisition System. This includes the

- location of the fires in latitude/longitude or mapping frame,
- fire status (out of control, being held, contained, suppressed, unknown)
- fire management district that is handling the fire,
- available thermal images of the fire.

The interface for this tool is still being developed, and the data contained in the reports is test data only not depicting fires that are actually burning or have burned in previous years.

### Trajectory Tool

Through the use of this tool, the user can view the trajectories of the spotter aircrafts that search for and monitor wildfires using the Data Acquisition System. To use this tool, the user can enter in the date of concern, and any airplane trajectories for that day will be displayed on the main map in the center of the screen. If any fires or hotspots were identified during a flight, the fire or hotspot will be marked on the trajectory with a fire icon. This type of tool could be useful for fire managers for they could see exactly where and when certain areas were monitored for fire and could then orchestrate future flights based on that data.

### Prometheus Tool

This tool is the most sophisticated tool available on the WMMS site. The Prometheus tool allows the user to investigate predicted fire spread and behaviour in any location in the province of Alberta. The backbone of this tool is the Prometheus Fire Growth Model, which was endorsed and administered by the Canadian Interagency Forest Fire Center (Prometheus, 2004). Alberta Sustainable Resource Development is the lead agency for the development of this application and permitted the Geomatics Department at the University of Calgary to use Prometheus in the development of the WMMS system. Prometheus is able to model fire behaviour based on the Canadian standard fuel types, Canadian standard weather indexes, and topography using the Canadian Forest Fire Danger Rating System (CFFDRS) (Prometheus, 2004).

The CFFDRS was first developed in 1968 to help forest managers model fire behaviour (Hirsh, 1996). Since the system's initial development, two subsystems have been added to monitor the effects of different fuel types and the effects of different weather parameters. The names of these two subsystems are the Fire Behaviour Prediction (FBP) System and The Fire Weather Index (FWI) System.

The FBP system uses fuel type, topography, weather parameters from the FWI system, foliar moisture content, and point or line ignition sources (Hirsh, 1996) to help predict how fire will spread through a landscape.

The FWI system is composed of six components that affect fire behaviour through fuel moisture and wind effects. The first three components are concerned with moisture content in different layers

of fuels on the forest floor. The remaining three components are predicted rate of spread, fuel available for combustion, and predicted fire intensity. All six of these components are calculated using the equations from (Van Wagner, 1985) to produce qualitative results that are used as input into the FBP system.

Prometheus was chosen as the fire behaviour model for this system because it possesses three key advantages over other models. The first is that it is a spatial model and allows the user to see the growth of each fire. The second is that it uses the CFFDRS, and the third reason is that it has an available Component Object Model which allows it to be easily integrated into a webpage application.

Component Object Models or COM's are a lower level form of the original application. They can be described as the original application coded into discrete parts or components. Each component is capable of performing a certain segment of the complete application. All the components can be used together to replicate the complete application, or additional components can be used with the COM to improve or change the original. This is made possible by following a strict development standard.

The Prometheus COM has been integrated into the WMMS webpage so that fire modeling can be performed by the users. On the website it can be accessed by clicking on the "Use COM" button under the heading "Prometheus Tool". In the screens that follow, the user is asked to enter in the desired parameters that will allow the Prometheus model to calculate a predicted fire growth perimeter. Since the scale of the map of Alberta is too large to see most fire

*continued on page 14*

continued from page 13

perimeters, the resulting fire will be marked with a fire icon until the user zooms to an appropriate scale.

## Managers Toolbox

This toolbox is only available to users with managerial status. It will be invisible to general users.

Tasks that can be performed using this tool include:

- updating user accounts (status, name, email),
- managing database information and files,
- confirming general user's submitted fires and hotspots.

## Conclusion

It is hoped that the development of this application will spark the imagination of some fire managers and influence them to integrate some of the elements of the WMMS into their own fire modeling systems. With further research and the continued development of geomatics technology in fire management, hopefully wildfires will be one natural disaster that mankind will be able to control.

## Acknowledgments

We would like to thank Cordy Tymstra from Alberta Sustainable Resource Development for the use of the Prometheus COM and Chuanyun Fei for programming the WMMS Website.

## References

- Bevins Collin. "FireLib User Manual and Technical Reference". Release 1, October 1996, URL: <http://fireorg/firelab/doc.html>, last date accessed 01 December 2004.
- El-Sheimy, N., and Wright, B., 2004. Real-time Airborne Mapping System for Forest Fire Fighting (F<sup>3</sup>) System, *Photogrammetric Engineering & Remote Sensing*, Vol. 70, No. 4, p. 381.
- Finney, M. A., 1998. "Farsite: Fire Area Simulator – Model Development and Evaluation", *USDA Forest Service*, Research Paper RMS-RP-4, 47 p.
- Grabner, K. 1999. Using BEHAVE as a prescribed fire planning tool in maintaining oak savannahs, Notes for Forest Managers, *Missouri Department of Conservation*, University of Missouri, URL: <http://mdc.mo.gov/documents/forest/managers/19991101.pdf>, last date accessed 01 December 2004.
- Hirsch, K. G., 1996. *Canadian Forest Fire Behaviour Prediction System: User's Guide*, UBC Press, Vancouver, B.C., Canada.
- Prometheus: The Canadian Wildland Fire Growth Model, Calgary, Alberta, Canada, URL: <http://www.firegrowthmodel.com>, last date accessed 01 December 2004.
- Rothermel, R.C. 1972. A Mathematical Model for Predicting Fire Spread in Wildland Fuels, *USDA Forest Service*, Research Paper INT-115, 40 p.
- Van Wagner, C.E., and T.L. Pickett, 1985. Equations and FORTRAN program for the Canadian Forest Fire Weather Index System, *Canadian Forest Service*, Ottawa, Ontario, Forestry Technical Report 33.
- Van Wagner, C.E., 1987. Development and Structure of the Canadian Forest fire Weather Index system, Canadian Forestry

Service, Ottawa, Ontario, Forestry Technical Report 35.

Wright, B. and El-Sheimy, N. 2003. Real-Time Direct Georeferencing of Thermal Images for Identification and Location of Forest Fire Hotspots, *6th Conference on Optical 3D Measurement Techniques*, Zurich, Switzerland, 22 – 25 September.



## Authors

**Landra Trevis** and **Naser El-Sheimy**

Mobile Multi-sensor Research Group  
Department of Geomatics Engineering  
The University of Calgary

## Edited by

Dr. Mohamed M.R. Mostafa, Applanix Corporation