Wildfire modeling through a mobile application

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Abstract

With increased frequency and intensity of wildfires around the world, new technologies are now emerging that may aid in confronting the disasters and minimize their impacts. Fire protection entities have begun leveraging wildfire behavior spatial modeling, as a tool to provide valid fire spread and intensity estimations used for fuel and vegetation management practices and early warning of potential or on-going wildfires. New mobile applications that integrate Geographic Information Systems (GIS) are also being applied to risk mitigation and disaster response management. In this study, we describe the development of a cross-platform mobile application that combines fire propagation simulations with mobile geospatial technology to create a wildfire decision-aid system for application on active wildfire incidents. Our mobile application (*MTT App*) provides a novel approach to harness new technologies to support real-time suppression efforts and improve firefighter safety.

Keywords: mobile GIS, cross-platform applications, fire behavior, Minimum Travel Time (MTT)

1. Introduction

Novel technological advances in mobile devices and applications can be exploited in wildfire confrontation, enabling end-users to easily conduct several everyday tasks, such as access to data and information, sharing of intelligence and coordination of personnel and vehicles. Mobile technologies have been emerged for risk mitigation and disaster response management, and the demand for additional tools continues to grow. A wide range of innovative mobile Geographic Information Systems (GIS) applications has emerged in recent years, including tools for collecting data across a range of disciplines in the earth sciences (Kwok, 2009). In particular, tools like ArcGIS Online[1] and ESRI Story Maps[2] offer novel geospatial mobile applications that can be deployed in multiple models and operational systems on smartphones and tablets, thus offering advanced GIS capabilities for users with little knowledge of GIS and programming. Mobile applications for the general public need to provide a wide range of useful information regarding active wildfire incidents. From the perspective of a professional firefighting service and civil protection authority, a wildfire mobile application should provide maps with abilities to visualize, query and update crucial and useful data for field operations and collect or send new information to emergency response centers. Such applications should also provide access to fire prediction information (i.e. ignition risk and fire behavior), access to weather data (current and predictions), routing services and spatial queries for the locations of closest facilities and support infrastructures. In this paper, we describe our efforts to leverage recent technical advances in the development of mobile apps to build a wildland fire mobile application called the *MTT App* that can be used as an operational tool for firefighting purposes. The *MTT App* integrates fire behavior predictions based on the Minimum Travel Time (MTT) algorithm (Finney, 2002) that is incorporated into a number of United States fire modeling systems, including FlamMap, FSPro and FSim (Finney, 2006; Finney *et al*., 2011; Noonan-Wright *et al*., 2011).

2. Methodology

Initially, a web application was implemented based on ArcGIS API for JavaScript[3], which enables the integration of geo-processing and mapping services from any GIS Server. The geo-processing services are executed to store the output spatial files from the MTT algorithm (parameterized as major flow paths, spread rate, time of arrival and fireline intensity of a wildfire) in a geographical database, while mapping services are used for displaying mapped outputs. The Dojo toolkit[4] and the JQuery framework[5] were incorporated to enhance cross-browser compatibility.To create an application compatible with a wide spectrum of mobile devices the Bootstrap framework[6] was used. Bootstrap adapts the content layout according to the user's device screen size and orientation. We added cross-platform capabilities with the integration of the Apache Cordova[7] open-source mobile development framework. Apache Cordova uses plugins to access each device's capabilities and enables the application to invoke native code from JavaScript to access device capabilities, such as the current location of the end-user based on the GPS receiver of the mobile device. Finally, the code was uploaded to the GitHub repository to make the mobile

[1] https://www.arcgis.com/home

[2] https://storymaps.arcgis.com

[3] https://developers.arcgis.com/javascript/

[4] https://dojotoolkit.org/

[5] https://jquery.com/

[6] http://getbootstrap.com/

[7] https://cordova.apache.org/

application available for every available operating system based on the PhoneGap Build Cloud[8] service.

3. Results

The *MTT App* provides access to key services for fire management, especially to end-users engaged in active suppression field activities. To utilize the available tools and services, users must be registered and provide credentials. Upon opening the application, and after successful authentication, the end-user location is tracked (received from the GPS sensor of the device) and visualized as a fire vehicle symbol on top of the topographic background map. By interacting with the Basemaps submenu, the end-user can choose a different background scheme from the available mapping schemes of Microsoft Bing Maps (i.e. hybrid, streets, imagery, national geographic and topographic). Apart from background layer selection, users have access to all water refilling sites and sources of Lesvos Island, Greece. This information is vital to support forest fire suppression efforts. Three types of water sources can be visualized: water tanks, fire hydrants and pumping stations. Each layer is available under the Fire Management Facilities submenu. After choosing the desirable layers, the available water sources are visualized. Finding the shortest routes from the current user's location and the location of the closest water tank, fire hydrant and pumping station can be shown through a geo-processing task. Each route is visualized by a different color (Figure 1). The first prototype of the *MTT App* was based on our previous work; i.e. the wildfire prevention and management platform AEGIS (Kalabokidis *et al*., 2016). To keep our prototype simple but fully functional, we implemented the system with existing geodatabases for Lesvos Island, Greece. Fire simulations within *MTT App* are conducted in a transparent procedure that offers several options to fine-tune and specify simulation parameters while relying on computing resources at a remote datacenter. When a fire simulation is executed (Figure 2-A), input parameters are submitted through AJAX (Asynchronous JavaScript and XML) and stored in a relational database. At the datacenter, the first available machine retrieves the input parameters of the simulation from the relational database and starts a new instance of MTT (Figure 2-B). If multiple users begin their simulations simultaneously, each simulation is assigned to one of the available Virtual Machines (VM). Upon the completion of execution (Figure 2-C), several output files are generated either in GRID ASCII format (time of arrival, fireline intensity, ignition point and spread rate) or vector files with major flow paths (Finney, 2006). After output files are created, several GIS geo-processing services are executed to convert GRID ASCII outputs to vector format and store them as feature classes inside a geodatabase (Figure 2-D). The application steadily sends new AJAX calls in a background process to retrieve the simulation status for as long as execution is in progress (Figure 2-E). Finally, GIS mapping services retrieve the appropriate information from the feature classes using a filtering process to select simulation outputs and display map outputs (Figure 2-F).

End-users are able to conduct fire behavior simulations or access and view previously stored simulations. The ignition point of a new event is specified either by the GPS sensor of the device or by inserting the event's coordinates. The MTT algorithm requires the following user input parameters:

1. Simulation's duration (in hours and minutes): To specify the duration, the end-user presses the "+" or "-" button to increase or decrease simulation time accordingly, up to a maximum duration of six hours, since MTT has a higher simulation accuracy for short-term time periods (Kalabokidis *et al*., 2014).
2. Wind speed and wind direction (in km/h): Real-time wind parameters (wind speed and wind direction) are retrieved by utilizing the OpenWeatherMap API[9] that gives access to current weather data. Real-time weather data from the OpenWeatherMap API are frequently updated based on global models from more than 40,000 weather stations around the world. Wind parameters can also be user-defined to conduct "what-if" scenario simulations. By changing the value of the wind direction value, the icon showing the wind direction changes, respectively.
3. Fuel moisture content (in %): These values (1h, 10h, 100h, live herbaceous and live woody) are calculated from the values of relative humidity and air temperature (retrieved by OpenWeatherMap API) by using the algorithm of Vinney (1991). Beyond measuring the fuel moisture content from nearby Remote Automatic Weather Station (RAWS), the end-user can use one of the standard fuel moisture scenarios of the BehavePlus (Heinsch and Andrews, 2010) software. By changing the fuel moisture conditions, end-users can conduct different simulations for different circumstances.

After providing the required inputs, users can press the "Start Simulation" key and then they are steadily informed for the simulation status for as long as the execution is in progress. Upon finishing of simulation, the time of arrival, fireline intensity and spread rate can be visualized (Figure 3). Previous simulations are accessed by interacting with the *Fire Behavior Modeling* submenu. Upon the selection of a past simulation, the application shows all input parameters and outputs including the ignition location, fuel moisture, duration of the simulation, wind parameters and MTT results.

4. Discussion and Conclusions

Technological advances in mobile devices and applications can be leveraged in real-time to improve safety and efficiency of wildfire suppression operations. Mobile applications can streamline a number of routine and critical operational tasks, such as access to geospatial data and information, sharing of intelligence on fire activity, and coordination of personnel and vehicles involved in response efforts. The Information Technologies used to achieve these goals include ArcGIS API for JavaScript, Dojo API, JQuery framework and Apache Cordova, in conjunction with the MTT algorithm that performs wildfire simulations. The integration of these technologies into a

[8] https://build.phonegap.com/

[9] http://openweathermap.org/api

mobile application created state-of-the-art fire management services using Web-based GIS and wildfire modeling. Outputs may potentially support civil protection and fire control services in the organization of innovative wildfire management plans, especially for end-users involved in fire suppression activities. The outcome can potentially contribute towards a more sophisticated knowledge transfer among the various entities involved in wildfire suppression activities, including operation centers and firefighting units in the field. In case of a fire emergency, end-users can utilize the mobile application at the field and retrieve crucial information such as how the fire will spread in the next hours. Our work advances the current suite of mobile wildfire applications by integrating a robust wildfire behavior modeling system. The MTT fire spread algorithm and the associated crown fire prediction models, as implemented through the FlamMap code libraries is by far the most widely used and tested fire simulation in the world (Kalabokidis *et al*., 2016). Extensive application has demonstrated that the Huygens' Principle and the MTT algorithm can be used to replicate large fire distributions and perimeters over a range of fuel types and weather conditions (Ager *et al*., 2007; Ager *et al*., 2012; Andrews *et al*., 2007; Finney *et al*., 2011). Holding fire weather conditions constant, the MTT algorithm searches for the fastest path of fire spread along straight-line transects connected by nodes (cell corners) (Finney, 2006) and exposes the effects of topography and arrangement of fuels on fire growth (Ager *et al*., 2012). To the best of our knowledge, this approach is the first that provides mobile fire event simulations to explore in real-time the potential spread and intensity of active wildfire incidents. The *MTT App* also includes geospatial functionalities useful for supporting active fire suppression activities, such as the calculation of the shortest routes and the location of water sources (i.e. the closest water tank, fire hydrant and pumping station). Our system was implemented as a cross-platform mobile application that allows implementation on a wide spectrum of mobile devices. Initial testing included installation of the *MTT App* on different types of mobile devices for the local fire authorities on Lesvos Island, Greece. The system is currently being tested throughout the 2016 and 2017 wildfire seasons. Initial feedback from the local wildfire management community has been positive and firefighters readily understood the application's interface and various functionalities. In particular, the ease of conducting mobile, real-time wildfire simulations via the interface was perceived as a significant technological advance for operational fire suppression activities. Future work includes wider application to a number of different geographic areas in Greece, and expanding the scale of the individual testing areas. Further research is planned to integrate additional functionalities, such as push notifications for new fire events in the area, tracking of the fire management fleet and the ability to upload live pictures from wildfire events.

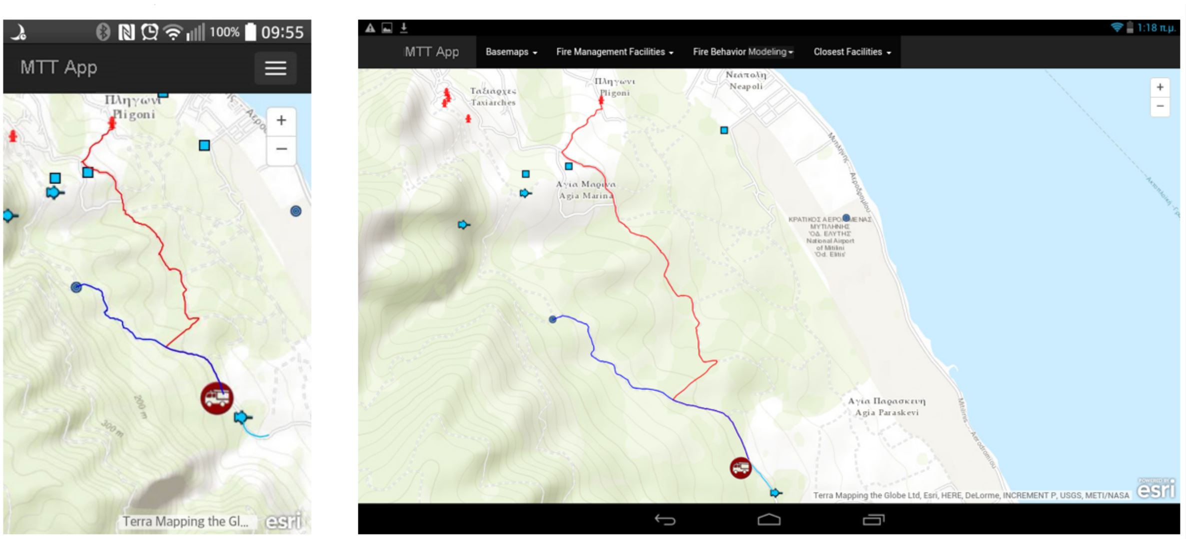

Figure 1: Visualization of shortest routes to the closest water sources in the *MTT App*, presented in a 4.3 inch smartphone device (left) and in a 8 inch tablet device (right)

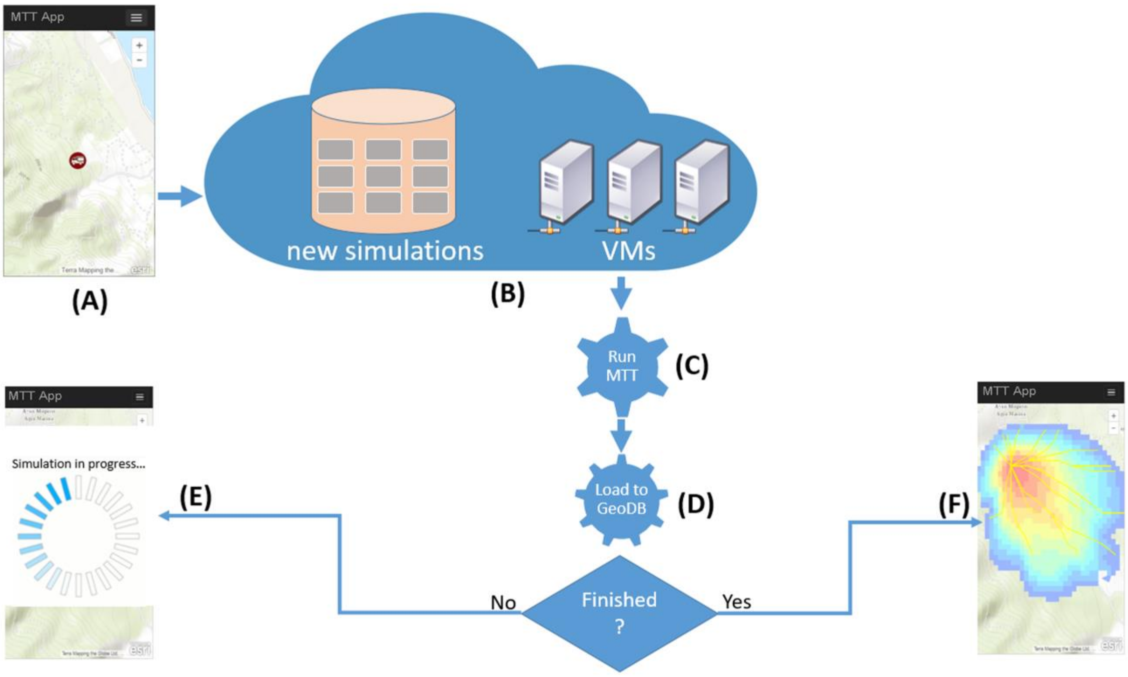

Figure 2. Minimum Travel Time simulations in the *MTT App*

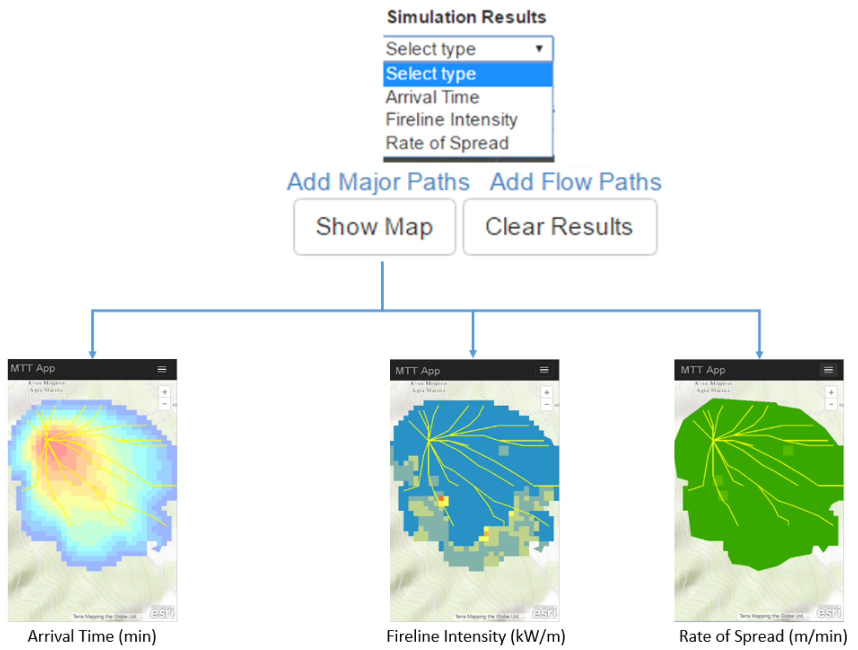

Figure 3. Visualization of MTT output results over the *MTT App*

References

Ager A.A., Finney M.A., Kerns B.K., Maffei H (2007), Modeling wildfire risk to northern spotted owl (Strix occidentalis caurina) habitat in Central Oregon, USA. Forest Ecology and Management, **246**, 45-56.

Ager A.A., Vaillant N.M., Finney M.A., Preisler H.K. (2012), Analyzing wildfire exposure and source-sink relationships on a fire-prone forest landscape. Forest Ecology and Management, **267**, 271-283.

Finney M.A. (2002), Fire growth using minimum travel time methods. Canadian Journal of Forest Research, **32**, 1420-1424.

Finney M.A. (2006), An overview of FlamMap fire modeling capabilities, in: Fuels Management – How to Measure

Success, edited by: Andrews, P. L. and Butler, B. W., USDA Forest Service, Rocky Mountain Research Station, 28–30 March 2006, Portland, OR, 213–220.

Finney M.A., Grenfell I.C., McHugh C.W., Seli R.C., Trethewey D., Stratton R.D., Brittain S. (2011), A method for ensemble wildland fire simulation. Environmental Modeling and Assessment, **16**, 153-167.

Finney M.A., McHugh C.W., Grenfell I.C., Riley K.L., Short K.C. (2011), A simulation of probabilistic wildfire risk components for the continental United States. Stochastic Environmental Research and Risk Assessment, **25**, 973–1000.

Heinsch F.A, Andrews P.L. (2010), BehavePlus fire modeling system, version 5.0: Design and Features. Gen. Tech. Rep. RMRS-GTR-249. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 111 p.

Kalabokidis K., Ager A., Finney M., Athanasis N., Palaiologou P., Vasilakos C. (2016), AEGIS: a wildfire prevention and management information system. Natural Hazards and Earth System Sciences, 16, 643-661.

Kalabokidis K., Athanasis N., Palaiologou P., Vasilakos C., Finney M., Ager A. (2014), Minimum travel time algorithm for fire behavior and burn probability in a parallel computing environment. In Viegas, D. X. (ed.): Proceedings of 7th International Conference on Forest Fire Research, Advances in Forest Fire Research, 17-20 November 2014, Coimbra, Portugal. Published by Imprensa da Universidade de Coimbra. ISBN 978-989-26-0884-6, pp. 882-891.

Kwok R. (2009), Personal technology: Phoning in data. Nature, 458(7241), p. 959.

Noonan-Wright E.K., Opperman T.S., Finney M.A., Zimmerman G.T., Seli R.C., Elenz L.M., Calkin D.E., Fiedler J.R. (2011), Developing the US Wildland Fire Decision Support System, Journal of Combustion, 14 pages.

Viney N.R. (1991), A review of fine fuel moisture modelling. International Journal of Wildland Fire, **1**, 215–234.