Smartphone Applications for Data Collection, Dynamic Modeling, and Visualization in the Wildland Fire Environment

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Introduction

Rapid advances in cellular phone technology have transformed portable telephones into "smart" phones; powerful, portable personal computers equipped with Global Positioning System (GPS), cameras, and a suite of tools for accessing and storing information. Smartphones offer the ability to connect to large servers via both cell and wireless networks with a speed and power that is truly remarkable when compared with what was available only 10 years ago. The sheer numbers of smartphones being used globally make them a potent tool for distributing, as well as collecting, information (Kwok 2009).

Smartphone applications (apps) are rapidly being embraced as a tool for collecting data across a range of disciplines in the earth sciences (Kwok 2009). Equipped with GPS, local time information, and a camera, smartphones can be a tool for collecting and storing environmental data. For example, weather modelers at the National Oceanic and Atmospheric Administration have developed and promoted an app called mPING (precipitation information near the ground, http://www.nssl.noaa.gov/projects/ping/) for collecting information about the form (e.g., hail, snow, rain) and timing of precipitation. Other applications in environmental sciences include collecting of epidemiological information (Aanensen et al. 2009) and identifying and recording the location of bird species (Wood et al. 2011).

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Perhaps the most obvious use of mobile technologies in fire management is in the collection and sharing of weather information. For firefighters, the ability to quickly receive the latest weather information is critical. Historically, weather observations were collected and shared via radio communications. The rise of mobile computing allows for digital sharing of weather observations and allows firefighters to access different sources of weather information through the variety of weather applications available for mobile devices. Rapid access to weather forecasts, observations, and supplemental environmental data have the potential to greatly enhance situational awareness and firefighter safety.

Weather observations are also a critical information source for supporting wildland fire management decisions. Currently, weather information during wildland fire incidents comes primarily from Remote Automated Weather Stations (RAWS). Data from the nearest RAWS are often used to model fuel moistures and predict fire behavior during an incident. However, stations may be located 31 miles (50 km) or more from the incident and are typically placed on south-facing, low-elevation slopes to capture "worst case" conditions. Thus, much of the spatial variability in fuel moisture and fire danger is typically ignored (Holden and Jolly 2011). Secondary weather information comes from wildland firefighters who measure and report hourly weather conditions in the field during active fire

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incidents. While weather observations from firefighters in the field may be less accurate than weather measured at RAWS, the ability to rapidly collect and disseminate weather information may outweigh any potential reductions in data quality (Goodchild and Glennon 2010). These weather observations are typically reported back to a central dispatcher via radio. They are sometimes used by spot fire weather forecasters, but typically remain in paper form, where they are largely inaccessible for further analysis after the incident. The observations, accumulated over time, represent a potentially rich but untapped source of weather and climate information. By embracing digital mobile technologies to collect and share weather information, we can improve decisionmaking and efficiency in fire management.

Methods

A number of smartphone applications have been developed to support wildland fire management. In this article, we will discuss a few specific developments designed to help managers and firefighters better monitor, share, and understand the fire environment. This list is not intended to be comprehensive, but rather, to illustrate a few specific examples currently in use and explore what the future may hold. It includes mobile-specific development, as well as existing science programs that are being modified for use in mobile environments.

Fire Weather Calculator

The number of weather applications available for mobile devices is stunning. These cover anything from sharing forecast data to interpreting clouds. In fire, however, the ability to use a mobile device to more efficiently calculate fire weather parameters and subsequently share those observations has lagged behind. The Fire Weather Calculator, developed by the National Center for Landscape Fire Analysis, is one example of a mobile app designed to add value to traditional weather observations. This application allows the user to input traditional observations (e.g., dry bulb, wet bulb, etc.) and have the application calculate critical information, such as relative humidity and probability of ignition, which both saves time and ensures consistency between weather observers. More importantly, however, is the ability to archive and share these digital observations with other users and managers in real time. This application allows for more streamlined management of weather information, a critical aspect of any fire event. The ability to share observations, particularly if many users are archiving their observations, will lead to a very useful archive of crowd-sourced data that will be used to create value-added products, such as the calculations of 3-dimensional weather fields that could be shared with personnel to increase their situational awareness.

The Topofire Weather App

The low cost of high-performance computing offers the potential to expand smartphone applications in wildland fire from simple data recorders to the frontier of real-time modeling and ecological forecasting. One example of this type of application is the TOPOFIRE application. Similar to the Fire Weather Calculator app described above, this application allows users to enter a suite of fire weather observations that are normally collected on incidents. These observations, as well as the time and location, are sent directly to the TOPOFIRE server, where they are permanently archived and can be made available to users and fire weather forecasters. Weather information entered into the phone can then be used to parameterize the WindNinja simulation model, using either current observations or gridded data from the Real-Time Mesocale Analysis dataset (RTMA). Users can also request forecasts for the next 3 to 12 hours, using data from the National Digital Forecast Database. Model simulations are then run on the TOPOFIRE server, and outputs are returned to the user's phone in the form of a keyhole markup language (.KML) file that can be opened on the phone on GoogleEarth. Although not currently enabled, additional weather variables can also be blended with the RTMA gridded weather model data to provide spatially corrected data for the domain around the fire incident using data collected onsite. Again, this type of two-way interface between phone users and a computer modeling environment demonstrates the potential for development of an operational environment whereby wildland firefighters dynamically inform and retrieve models of the fire environment in real time. Further, these data could be provided immediately upon collection to the fire behavior analysts who are charged with observing and forecasting fire behavior and who typically provide local weather observations to the National Weather Service to improve their incident Spot Weather Forecasts.

Figure 1. *The TOPOFIRE smartphone application assimilates weather observations and photographs from wildfire incidents, which can be used by fire managers and fire weather forecasters. Users can also request WindNinja simulation and fire danger forecasts via phone in real time.*

The TOPOFIRE Photologger App

Photographs and videos are another key source of information collected during fire incidents. Firefighters are often asked to take pictures or videos of fire behavior to share with incident commanders. Development of tools for rapidly sharing images could dramatically improve communication and could potentially improve situational awareness at every operational level within an incident. Mobile phones now routinely embed location and accurate timestamps into photographs, facilitating the integration of these resources into Geographic Information System applications. One example currently under development is the TOPOFIRE photologger app, which allows users to collect images and videos with a smartphone and send them directly to a central server where they can be queried spatially and viewed almost instantly by others.

Open Data Kit (ODK)

Applications like ODK (http://opendatakit.org/) allow users to translate standard "form" information to digital formats for use on mobile devices. Any kind of form that managers and firefighters currently use can be converted and modified to be easily read and filled on a mobile device. For example, smoke-management observations, critical to many aspects of fire management, can be implemented in a digital framework that allows for simplified data collection and archiving. The form, once converted, can be used for multiple independent observations. The native digital format allows for embedded error checking, ease of transfer, and subsequent access. Gone are the days of transcription from paper to digital media and the inherent problems associated with the management of those systems.

Future Challenges

Despite the clear potential for integrating mobile computing technologies into operational fire management, a number of organizational, technical, and logistical challenges lie ahead.

Arguably, the largest impediment to wide-spread adoption of mobile technologies is the issue of operating-system specificity (iOS, Android, etc.) and central information technology (IT) issues. An ongoing debate is which device fire managers should embrace as the default. The merits for picking one operating system over another are beyond the scope of this article. In reality, devices that use Android and iOS operating systems are widely used and are unlikely to disappear. We suggest fire managers consider the decision made by the U.S. Department of Defense and embrace the idea of device agnosticism (USDOD, CIO 2013). This idea dictates that the fire organization would not choose a specific operating system as a standard. Committing to a single operating system/company could lessen the chance for innovation through competitive development.

Instead of setting standards for devices, fire managers would be better served setting standards for data acquisition and management. What are the important data sources? How should those sources be used and managed? What are the true efficiency and information gains? Once those are decided, applications should be developed to support all mobile devices. The development of monolithic standards should be avoided in order to maintain efficient mobile device integration. If comprehensive standards are defined, however, they will almost certainly always lag behind the most current technological advances, resulting in lost efficiency. Recent advances in cross-platform mobile development that leverage HTML and Javascript available on most current mobile devices show promise in allowing the development of applications for most operating systems from a single codebase.

The Way Forward

Collecting, managing, and distributing weather information is just one example of how mobile devices can and will revolutionize wildland fire operations and management. As mobile devices become more powerful and data coverage increases, mobile computing will truly become a vital technology. Mobile devices will allow better collection of critical fire and environmental data while simultaneously allowing data to be converted and quickly shared.

In an era where computing power has become relatively cheap and widely available, a dynamic two-way interface between phone users and computer models running in real time is now possible. Fast connectivity via broadband wireless networks allows rapid sending and retrieval of remotely generated data. This dynamic link between phones and computers has the capacity to expand smartphone applications in environmental sciences from simple data recording and sharing into the next frontier of real-time modeling and forecasting.

One example of using field data to quickly provide useful information is the TOPOFIRE application discussed above. The user can provide weather information that feeds a model that provides comprehensive environmental information back to the user within minutes. In the future, one can easily imagine these observations being used to parameterize and calibrate models that quickly return 3-dimensional fire weather data, hydrological and fuel-model information, as well as continuously updated, next-generation fire danger models. The goal of these products is to increase situational awareness and support more efficient and precise decision-making.

Nearly every "smart" mobile device on the market is now equipped with a GPS, making each device spatially aware. A new frontier for fire management lies in the ability of a central server to send or "push" critical information about changing conditions to mobile devices. For example, Fire Weather Watches and Red Flag Warnings are commonly issued by the National Weather Service to highlight regions where wildfire weather conditions may promote intense fire behavior (Figure 2). Future systems could send this critical information as soon as a Watch or Warning is issued to any person who has a phone and is within these areas. This rapid dissemination of this information could be life saving.

Mobile devices are also powerful mapping tools. We are already seeing how these devices are changing the way managers use spatial information in the fire environment. From portable document format (PDF) maps that provide real time context and location information, to geotagging of photographs and field data, there is obvious potential to use portable devices to provide spatial data about the firefighting environment. In the future, these capabilities will improve as we continue to develop a better understanding of disturbance and ecological processes. For example, we will soon have the ability to track Mountain Pine Beetle infestations and monitor changes more effectively by using mobile technologies. With more information and increased understanding, one can easily envision tools that share state-of-the-science information with field personnel. When coupled with improvements in fire behavior modeling, it's easy to see how this direct, real-time connection between observers, the environment, and modeling tools could be used to enhance the awareness and safety of firefighters, while allowing for more rapid and accurate decisionmaking.

In the near future, we will also see a dramatic rise in the use of sensors and wearable technologies. We are already seeing "wearables" playing an interesting role in how we perceive mobile computing. Google Glass® and the Apple Watch® are examples of what's to come. One can easily imagine technologies that continuously monitor firefighter health, collect weather data in real-time using sensors connected to the phone, and track their locations in real-time using the phone's GPS. Bluetooth® connectivity on mobile devices also makes each device a potential hub for any auxiliary wireless device. For example, handheld digital weather instruments, such as Kestrels®, can wirelessly relay information directly to the mobile device without human intervention, making weather tracking more seamless. The continuing development of augmented reality systems shows some intriguing possibilities in how firefighters can interact with each other as well as the fire environment. If all of these technologies are used in a coordinated effort to monitor personnel activity during wildland fire incidents, they will likely lead to some remarkable changes in wildland fire management.

The key challenges for fire managers considering using these technologies will be how to select and implement the latest tools and, afterwards, to find effective ways to monitor and evaluate the tools they select. This is not a time for monolithic decisions, rather, fire managers need to be able to identify the best and most *appropriate* tools that can truly support decisionmaking while *not* forcing firefighters to conform to outmoded standards or use less effective tools. Technologically speaking, this is a very exciting time for wildland fire management—the challenges will be in finding a way to efficiently navigate this rapidly changing field in order to bring the best digital tools available to improve how we manage natural resources.

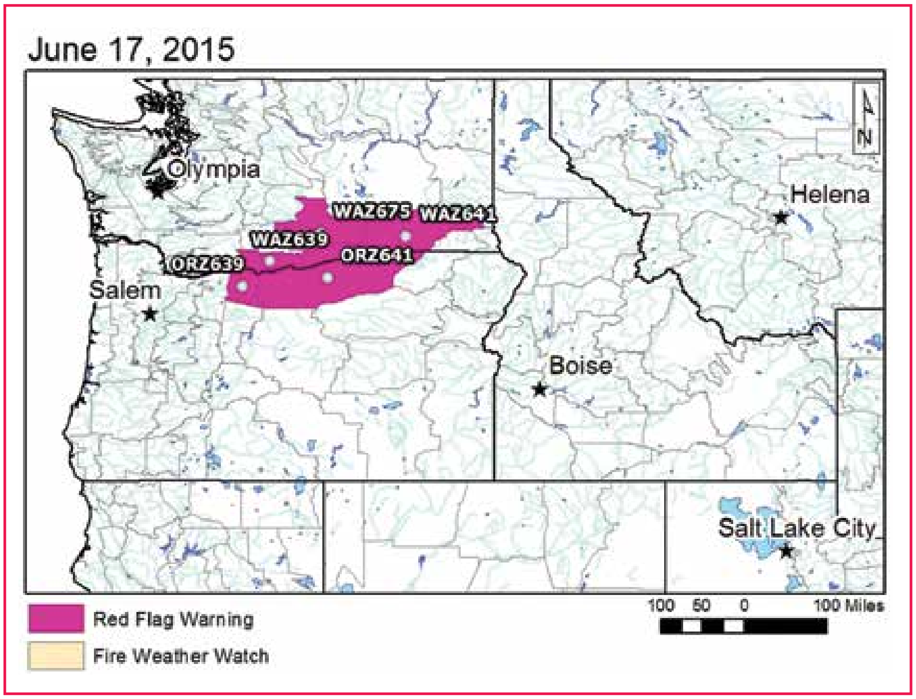

Figure 2.—*Example Red Flag Warning Map for the Western United States from June 17, 2015. Source: http://www.wrh.noaa.gov/firewx/main.php.*

References:

Aanensen, D.; Huntley, D.M.; Feil, E.J.; al-Own, F.; Spratt, B.G. 2009. EpiCollect: Linking smartphones to Web applications for epidemiology, ecology and community data collection. PLoS ONE. 4(9): e6968. doi:10.1371/journal.pone.0006968.

Goodchild, M.F.; Glennon, J.A. 2010. Crowdsourcing geographic information for disaster response: a research frontier. International Journal of Digital Earth. 3(30): 231–241.

Holden, Z.A.; Jolly, W.M. 2011. Modeling topographic influences on fuel moisture and fire danger for improved wildland fire management decision support. Forest Ecology and Management. 262: 2133–2141.

Kwok, R. 2009. Phoning in Data. Nature. 458(23): 959-961.

Wood, C.; Sullivan, B.; Iliff, M.; Fink, D.; Kelling, S. 2011. eBird: Engaging birders in science and conservation. PLoS Biology. 9(12): e1001220. doi:10.1371/journal.pbio.1001220.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration. The mPING project. 2013. <http://www.nssl.noaa.gov/projects/ping> (1 April 2014).

U.S. Department of Defense, Chief Information Office (USDOD, CIO). 2013. Department of Defense commercial mobile device implementation plan. <http://www.defense.gov/news/dodc-Mdimplementationplan.pdf>. (9 June 2014).