Fast and Reliable Wildfire Smoke Detection based on Self-learning and Interactive Functionalities to provide useful Early Detection

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Abstract

Every year, the risk for fast spreading Wildfires is increasing as the past Wildfire statistics proofs. Analysis show, that fire suppression effort have been effective to stop most fires by a successful initial attack. Over 97% of wildfires kept less than 1,000 acres and 99% less than 10,000 acres (Havlina et al. 2015, Murphy et al. 2013). The probability of a successful initial attack and to avoid megafires, decreases exponentially with every minute passes after ignition. So, in the same rate as the danger increases, the requirements and demands increase to detect a starting fire as quick as possible after the ignition and analyse the precise location of the fire.

While in populated areas smoke plumes are reported quit early once they become visible, still the fire position is not clear (Cao, J; Boruff, B.J. & Mc.Neil, The smoke is rising but where is the fire?..). Also starting night fires will not be detected in a early stage and in this cases, a initial attack is mostly too late to be successful.

Vision sensor based detection methods can be a tool to provide reliable Early Detection and precise fire information. Most of the available technology generates much to high false alerts as well as late detection while the detection range is limited to visibility. If video technology is used, smoke can be only detected when a smoke plume appears with clear density. But if a smoke plume is visible, it’s almost late for the fire fighting resources to approach the fire place in time to perform a successful initial attack. Such parameters lead to low user acceptance and detection benefit and utilized vision detection systems are not operated for detection, but more and more for monitoring tasks. The presented detection solution describes a sensor solution in combination with the software, detecting smoke, not depending on density of a smoke plume, providing real “Early” Detection at minimized numbers of false
alerts. The self-learning functionality considers changing environmental and geographic situations as well as interactive user inputs, for a continuous adapting and optimizing of the detection algorithm to generate high quality detection information to the Fire Management and the involved Resources.

**Keywords:** Smoke detection, Early Detection, Self-learning, False alert elimination, Interactive operation

**Introduction**

Worldwide fire statistics reflect the global climatic changes where the numbers of wildfires may decrease while the areas burned as well as the fire suppression costs increases.

![Graph](image)

**Fig. 1.** Area burned, number of fires and suppression costs (inflation adjusted to 2016 equivalent) for the USA with linear trend lines (1991–2015) [1].

But only 2 - 3 % of all fires causes more than 95 % of the annually burned area. Even when in our densely populated world rising smoke is often reported by phone, still there are two uncertain factors:

- a) When rising smoke is clearly seen, the fire is already developed
- b) In the most calls, the fire position is not identified (The smoke is rising but where is the fire? [2])

The Forestry Handbook of British Columbia reports about expanded researches on spreading and acceleration of wildfires and comes to a theoretical, but also international commonly understanding timeframe of 30 minutes which a wildfire in timbered fuels take to reach its equilibrium rate of spread. The efficiency of an initial attack is as higher as it is performed before this 30 minute timeframe after ignition of the fire.
This requires reliable fast detection and of much more importance - precise location of a starting wildfire.

Today, several technologies to detect forest fires are available on the market and in operation. Most of them are not useful for early detection and even more, almost all are not useful for automated detection. Video based systems can detect smoke when its seen clearly, mostly to late to reach the time range to launch an initial attack within 30 minutes after starting fire as many wildfire examples actually shows. Optical systems generates, due to the environmental variations, so many false alerts (alerts, not caused by a wildfire but because of unclear environmental situations) that the operators cannot use them as an automated smoke detection system, as the effort to select alerts is high [8].

The paper describes an approach to provide a long range early detection system which delivers precise location data of a starting fire in order to fit - on one side the timeframe for a initial attack and – on the other side to reduce alerts, not related to a fire, to a minimum number in order to make a system reliable and accepted by the operator [9].

**Reliable and useful “Early Detection”**

To determine parameters and values which defines and specify a “Early Detection”, a simple possible way to get such values, is to review the achieved timeframe of 30 Minutes back to front. When the fire fighting aircrafts takes 15-20 minutes to reach the fire point, a “Early Detection” system has to provide reliable fire data within 5 minutes after ignition [3]. As most of the starting fire does not develop large quantities of smoke within this target detection time, and therefore not clearly visible, video detection as well as human detection is often too late to organize a efficient initial attack. In addition to such late detection result, exact fire location is unclear or completely missing. There is technology available, utilizing efficient Sensors, combined with variable spectrum analysis software and powerful detection algorithms makes it possible to identify smallest smoke portions starting at approximately 10 % - 15 % contrast ratio in the environment, ref. Fig. 2-3 [4][5].

![Diagram of the detection process in principal.](image-url)
Fig. 3. Detection of a small starting fire in 28 km.

Such demands on high sensitive and fast detections, the extreme dynamically changing environment rises up with new claims and requirements to ensure the alert quality, focussing on detecting and alerting only the real wildfires. Climatic changes, weather conditions and geographical and environmental situations may cause massive bulk of alerts, not related to a fire (false alerts). While well aligned detection parameters on good environmental and weather conditions an excellent alert quality is generated, might this change rapidly at changing weather conditions to such high false alert rates, that an operator feel uncomfortable to work on the system, ref Fig 4.

Fig.4. False alerts caused by cloud-shadows rising on shining rocks.
In order to respond on such changes in environmental situations, several assigned parameters for the detection algorithm would have to be modified and adapted permanently. Impossible and not to handle manually by an operator during normal work. The only way to respond on such variation of conditions can be an automated adapting of parameters. But a big challenge is the absence of the third dimension (depth, distance) at commonly used optical detection system which is limiting the identification of the situation related to the geographical situation probably a basic prerequisite for developing automated algorithms.

**Basics for self-learning functionality**

Video based detection systems are normally georeferenced in the azimuth axis (north-referenced) only. This described approach requires also the referencing of the elevation angle of the sensor (Fig 5) in order to extract Georeferenced Vector Data and Orthorectified Raster Data from the sensor information.

Fig 5. Referencing of sensor elevation.

Integrating and adapting a software tool to extract georeferenced vector data and orthorectified raster data from oblique non-metric photographs [6] will provide very exact image projection inside a map. The identification of positions in the map, related to fixed points in the image, might be finally indicated with an accuracy of < 10 - 15 m. That makes it possible to identify a fire position at a very high accuracy, even in hilly and difficult terrain. In addition to this excellent precise location of fires, each geographic point can be associated to any occurring and changing situation in the environment Fig 6.

Fig. 6. Extracting georeferenced data from images.
Interactive and Self-Learning alert quality improvement

Utilizing the described methods, it will be possible to generate tuned parameters and values which are processed with the detection algorithms. Many information and data can be integrated by connecting with an external sensor or by an interactive operator input (Fig. 7).

Assigning Image information to dedicated geographic positions into a map, all detection results from the detection algorithms generated will be checked for plausibility in different examination steps. One of the first steps is the geographic situation, in case of clouds, see, mountains without trees for example, the smoke source must result from an image area where a fire source might be possible. If there is a road with vehicles causing the alert, there are several other parameters has to be matching to identify such events as a fire alert. In addition to the geographic factors other environmental effects can be considered and integrated in the process.

At strong winds - as we find quiet often at areas at risk of fire -, the smoke behaviour is much different (sometimes moving on the ground), compared to fires under less windspeed and strength (rising up with a high dynamic movement and exploration). Corresponding values are matched to such environmental and geographical situation, adapted to the different changing conditions and will be optimized permanently during system operation. They will be continuously implemented into a parameter database improving the detection with every detection process following machine learning algorithms procedures [7]. With each new image processing and analysis the features derived are processed to different models like KNN (K-nearest neighbours), K models or gaussian distribution models, separated in the dynamic image information like smoke and or moving objects and static / geological
image information or semi-variable Information like colour of the objects and appearances in the image.

Beside the image derived data, information and features from other, external sensors and interactive operator data are considered in separate models and algorithms. Multiple models are merged to improve and optimize complex analytics in order to improve the alert quality to real fire related alerts. It is achieved to reduce the false alert rate at each weather and environmental conditions by more than 90 % to provide a reliable, fast and operator friendly Automated detection system.

Conclusion and Outlook

Early Detection for wildfires is still not a specified system definition. Many approaches and technologies are available but when following the yearly and actual wildfire reports, there is no real beneficial results noticeable. Feedbacks from Forestry organisations, utilizing different types of optical detection systems, claiming often the late detection, missing location of fires and high numbers of alerts. The described approach results already in fast detection, high precision location and reduced numbers of fails alerts. Still, standardization may be a future way to define parameters like detection time, detection distance, detection quality and definitions of information like fire location data, such detection systems should provide for user as well as defined interfaces to interchange the derived data to an attached Fire Management System [5].

References

[1] Figure 1 Area Burned, number of Fires.... Data: National Interagency Fire Center, https://www.nifc.gov/


[8] Jesus San-Miguel-Ayanz, Nicholas Ravail, Vaino Kelha, and Anibal Ollero, Active Fire Detection for Fire Emergency Management: Potential and Limitations for the Operational Use of ...