EMERGING METHODS FOR EARLY DETECTION OF FOREST FIRES

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ABTRACT — Forest fires are occurring throughout the year with an increasing intensity in the summer and autumn periods. These events are mainly caused by the actions of humans, but different nature and environmental phenomena, like lightning strikes or spontaneous combustion of dried leafs or sawdust, can also be credited for their occurrence. Regardless of the reasons for the ignition of the forest fires, they usually cause devastating damage to both nature and humans. Forest fires are also considered as a main contributor to the air pollution, due to the fact that during every fire huge amounts of gases and particle mater are released in the atmosphere.

To fight forest fires, different solutions were employed throughout the years. They ware primary aimed at the early detection of the fires. The simplest of these solutions is the establishment of a network of observation posts – both cheap and easy to accomplish, but also time-consuming for the involved people. The constant evolution of the information and communication technologies has led to the introduction of a new generation of solutions for early detection and even prevention of forest fires. ICT-based networks of cameras and sensors and even satellite-based solutions were developed and used in the last decades. These solutions have greatly decreased the direct involvement of humans in the forest fire detection process, but have also proven to be expensive and hard to maintain.

In this paper we will discuss and present two different emerging solutions for early detection of forest fires. The first of these solutions involves the use of unmanned aerial vehicles (UAVs) with specialized cameras. Several different scenarios for the possible use of the drones for forest fire detection will be presented and analysed, including a solution with the use of a combination between a fixed-wind and a rotary-wing UAVs.

In the next chapter of the paper, we will present and discuss the possibilities for development of systems for early forest fire detection using LoRaWAN sensor networks and we will analyse and present some of the hardware and software components for the realisation of such sensor networks.

The paper will also provide another point-of-view, which will present the involvement of students in the development and in the use of both systems and we will analyze the advantages and the benefits, which the students will gain from their work on and with these solutions.

Keywords — early forest fire detection and prediction, wireless sensor
network, machine learning, and artificial intelligence

INTRODUCTION

Forest fires have been and still are a serious problem for the European Union and all other countries in Europe.

In the year 2000, the EU established the European Forest Fire Information system (EFFIS), which will soon become part of the European Emergency Management Service, is maintained by the Copernicus Earth Observation Programme. This system provides valuable near real-time and also historical data on the forest fires in Europe, the Middle East, and North Africa. Currently, EFFIS is being used and supported with data by 25 EU member states and by numerous other countries.

According to the annual report of EFFIS for 2016, more than 54 000 forest fires have occurred all around Europe and they have led to nearly 376 thousand hectares of burnt areas. If we compare these values to the average values from the EFFIS reports for the period 2006-2015, the number of forests fires have decreased by 13327 or by nearly 20%. This decrease can be explained by the more severe actions and sanctions towards the arsonists and with the introduction of more advanced technical solutions for early detection of fires.

Even though their number is decreasing, the forest fires continue to be extremely devastating events and they have destroyed just 27 thousand hectares (or 6.6 %) less than the average burnt areas for the period 2006-2015, according to. Confirmation of this is the devastating forest fires form 2018, which took place in the Attica region of Greece and led to more than 90 fatalities and to more than 200 injured people, as well as the destruction of thousands of buildings.

The most important factors in the fight against the forest fires include the earliest possible detection of the fire event, the proper categorisation of the fire and fast response from the fire services. Several different types of forest fires are known, including ground fires, surface fires and crown/tree fires. Each of these types of forest fires is specific and the proper counteractions against it must be considered and implemented to successfully fight it. Over the years the detection of forest fires has been conducted in different ways, ranging from the use of forest outposts to fully automated solutions.

In the last decade many improvements in the forest fire detection technologies have been made. The modern IR cameras provide steady and reliable detection of the fires, but the real focus is set on the possibilities to detect the fires by analysing wider areas for smoke or by sensing the environmental parameters before the actual spread of the fire.

LITERATURE REVIEW

Arrue et al. (2000) [15] proposed a system for false alarm reduction in infra-red forest fire detection. The Back Propagation Network (BPN), The Radial Base Function Network (RBFN) and Dynamic Learning Vector Quantization (DLVQ) approaches inare used. Meteorological Geographical information data, the visual camera and the infrared camera data are the datas used. False alarm rate is 1.93% and detection rate over 98% are the main reported results.

Yu L et al. (2005) [2] proposed a real-time forest fire detection with wireless sensor networks. This method used MLP along with WSN. Temperature, relative humidity, smoke, wind speed data were employed. Resulting with the average communication load ratio (with NN method and the one without NN method) in range of: 2.5% (100 sensor nodes) to 8% (50 sensor nodes).

Vasilakos et al. (2009) [3] proposed a method that identifies wildland fire ignition factors through sensitivity analysis of a neural network using MLP and BPN. The method analyzes meteorological data, vegetation and topological data and the presence of humans. The percentages of the most influencing variables are 35.9%, 28.7%, 60.3%, 16.9%, 17.3%, and 14.3% for occurrence of rainfall in the last 24 h, temperature,10-h fuel moisture, aspect, primary road network and month of the year respectively.

Maeda et al. (2002) [1] proposed a method to predict forest fires in the Brazilian Amazon using MODIS imagery and artificial neural networks such as Multilayer feedforward networks (MLFN). Its task is to find the high risk FFD based on information in pixels of multi-temporal satellite images. The NDVI composite MODIS dataset is used. The author reported that the method resulted in an accuracy of 90% along with a MSE value of 0.07.

Dimuccio et al. (2011) [4] did a regional forest-fire susceptibility analysis in central Portugal using a probabilistic ratings procedure and artificial neural network weights assignment. GIS based data were used to do a task of forest fire map construction with the approach of back-propagation neural network (BPN). Resulting with an agreement of 78%.

Chen et al. (2003) [5] proposed a method for fire detection based on multisensor data fusion. It is based on fuzzy logic in wireless sensor networks (WSNs). The information such as temperature, humidity, CO and smoke are collected from the WSNs for the fuzzy logic based fire detection and home monitoring system. The authors reported the method resulted with an error ratio of 6.67% after testing 30 sample data.

Toreyin et al. (2005) [12] proposed a flame detection method in videos using hidden Markov models. A Markov model based on flame detection was used to analyze 11 color videos for the flame flicker process modeling. The authors reported that the processing time for an image of size 320x240 was about 10 msec.

Vapnik et al. (1999) [6] proposed a method for the prediction of burned areas with the SVM approach on meteorological data. The authors reported that the prediction method had predictive results of 13.07 and 64.7 in MAD and RMES respectively.

Park et al. (2019) [9] developed a dependable fire detection system that adopted a combination of multiple AI frameworks that includes the CNN (for the image data analysis), the deep NN (for sequential data analysis) and the adaptive fuzzy logic (for fire probability computation (decision)) algorithms. The authors reported accuracy about 95%. The CNN is widely used for the fire detection in images; the combination of CNN with other MLs such as the SVM and the fuzzy logic enhances the performance of such systems and reduces the end-to-and delay (data transfer and decision delays) in comparison to the legacy fire detection systems.

Habiboglu et al. (2012) [10] proposed a covariance matrix-based fire and flame detection method in video. This method adopts the usage of the Bayesian Belief Network (BBN) on the Satellite-based fire dataset, MODIS. Its task is to do the selection and ranking of biotic,abiotic and human factors that influence forest fires activity from videos. The reported results of recall, specificity and AUC are 0.963,072 and 0.961 respectively.

Bahrepour et al. (2010) [11] proposed a forest fire detection along with multi-sensors WSN using the Naive Bayes approach. Data such as temperature, humidity, smoke and light sensors were collected and gathered from multi-sensor WSNs. The method was reported to have a precision of 94%.

Saoudi et al. (2016) [8] proposed a method for video-based fire detection which uses a rule-based images processing algorithm. Datasets were created from fire videos and fire-like objects video. The results resulted in 93.13%,92.59%, 92.86 for the recall, precision and F-score with a false detection rate less than 40%. In the case of the naive Bayes model about 94% precision was observed as reported.

Cheng et al. (2011) [13] proposed a fire detection system based on Neural Network; here neural network is used in detection information for temperature, CO concentration, and smoke density to determine probability of three representative fire conditions. RBF neuron structure is used, the information regarding temperature, CO concentration, and smoke density are collected and data fusion is used to generate fire signal decisions. The detectors have continuous analog outputs, when the detection limit is exceeded the hardware circuit sends a local fire indication to the fusion center, this forces the system detectors to generate the final decision. Single-sensor detector is used to generate the final decision.

Kinaneva et al. (2019) [14] developed a forest fires detection system based on two UAV types (a fixed-wing drone and a rotary-wing drone). The two UAVs involved in this platform detect the data captured by their thermal cameras. The data was processed locally since the UAVs include on board processing units. The two UAVs were connected to the base station to send information about their captures. The model recognizes the smoke in the forest images sent by the UAVs and classifies them by means of the neural network model. In their previous work [16]; the authors used UAVs with fixed and rotary wings in addition to the Long Range (LoRa) digital wireless communication technology (LoRaWAN) sensor networks.

Mauhmoud et al. (2018) [7] developed a fine-tuned CCN surveillance camera based fire detection model (FFD in images) using the CNN method which was used upon 68,457 images that were taken from CCTV surveillance cameras. The reported results in terms of accuracy, precision, recall and F-measure were about 94.39%, 82%, 0.98 and 0.89 respectively.

CONCLUSION

In this work, we reviewed numerous techniques for predicting and detecting forest fires that have been proposed. The literature-reported studies demonstrate that machine learning techniques are extensively employed for the prediction of forest fires for both detection and prediction. Researchers focused primarily on the incorporation of the artificial intelligence used primarily in WSN and UAV-based forest fire modelling systems for monitoring forest fires.

The evaluated papers show that logistic regression and neural networks. Based strategies for fire detection and prediction are frequently employed. The supervised multi-layer ANN is the most common ANN model, and it exists as a single entity, or included in systems that use WSNs to monitor fires. As evaluated in a number of works, the utilization of multi-sensor data in a forest using neural networks.

We believe that the purpose of the current publication is to provide researchers with
a summary of the most advanced techniques for predicting and detecting forest fires that signify an unresolved problem. On the other side, it facilitates the firefighting effort to mitigate the forest fire risk by addressing such important environmental issues and supporting public policies in the control of forest fires.

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