ADVANCES IN FOREST FIRE RESEARCH

2022

Edited by

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Low-cost solution for forest fire detection using surveillance camera

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Keywords

Remote sensing, active fire detection, surveillance camera, efficiency, cost-effectiveness

Abstract

Nowadays climate change is one of the biggest challenges in the entire world. The average temperature on Earth is constantly increasing, and the distribution of seasonal precipitation is extreme. These factors together result in large fires and the new challenges require new solutions. The paper discusses the possibilities of developing the detection of outdoor fires with a camera. One of the objectives of the research is to prove the existence of a detection system by examining the detection conditions of outdoor fires and supporting them with practical examples. The research was determined to keep the costs of the examined developments below the value of properties they saved, so authors consider it a realistic aim to apply them in practice. Another objective was to demonstrate the time gain of the detection of remote sensing. In each case, the comparative analyzes of the authors show that citizen reports, i.e. the current, traditional solution, allow for a later alert than it would have been possible by using remote sensing. In the paper, wildfires were analyzed that were randomly recorded by video cameras. Authors have collected data on the specific fire from various official databases of the Hungarian Disaster Management. Taking into account the speed of fire propagation, it was determined that the burned area and perimeter of the fire are much smaller than the early detection when the firefighters arrive to the site. It shortens the length of the frontline to be extinguished. This predisposes to a lower force requirement for elimination and also significantly reduces the use of intervening forces along with the need for the used extinguishing agent. Overall, the intervention can be made more effective.

1. Introduction

In Europe, wildfires are most common during the summer fire season, due to the high average temperature and the quantitative distribution of precipitation. As a result of climate change, droughts have become common in the summer. In this case, no open flame is needed to ignite the dry fuel, a spark bursting from a machine can also do it. Combustion of accumulated combustible fuel releases enough thermal energy to cause even crown fire. Outdoor fires cause enormous damage to animals and wildland vegetation that can only be recovered in decades. By outdoor fires authors mean fires in the forest, wildlands, agricultural lands, grass, shrubs, forest litters, so they are talking about a collective concept.

The problems associated with fighting against forest fires are also very diverse, and their solution requires different tactics. If a fire already develops, it is important for everyone to put it out quickly and professionally with the least possible effort. Therefore, fast and accurate fire detection is very important for the efficiency. It is a negligent behaviour to rely solely on passive detection in case of outdoor fires. The later we become aware of fires in our environment, the more tools and forces we need to extinguish them successfully. The most effective solution for monitoring large areas is remote sensing. Nowadays, the presence of cameras is already common, it is no longer a big challenge for modern technology to produce devices suitable for high-quality images at minimal cost. All people have smartphones in their pockets whose cameras can take clear pictures. If the presence of cameras is so much part of our everyday lives, its benefits could also be used to support disaster management operations.

There are many papers focusing on camera based fire detection, some of them give a review of the technology (Alkhatib 2014, Mathi and Latha 2015, Yandouzi et al. 2022), others focus on the option of autonomous detection (Breejen et al. 1998, Liyang 2005, Saponora et al. 2018), the network system (Benzekril et al. 2020, Muhammad et al. 2018), the machine learning technology (Byongjun 2019, Xu et al. 2021) or the optimization of the detection (Restas et al. 2014, Quttineh et al. 2022).

The purpose of this study is to analyse the low-cost webcam videos of the locations where the fire occurred and then present the time difference between the occurrence of the fire alarm and the optional fire detection. Authors intend to demonstrate even the difference between both the sizes of burnt areas and the lengths of perimeters in cases of active and passive detection.

2. Methods

We have examined and analysed the relevant literatures on the topic as well as the results of other authors. Part of the secondary research was the analysis of reports, data and webcam recordings of outdoor fires. The data on the alarm sheet provided by the fire service were studied and compared with the remote sensed recordings provided by the webcams. Using the timestamp of the recordings and the data on the alarm sheet, authors performed basic calculations from which comparisons were made and logical conclusions were drawn. In addition, authors analysed figures, signalling dates and damage descriptions through the statistical service of one of the online interfaces of the Hungarian Disaster Management. In addition to the practical experience of the authors, they received information about related examples during consultations with firefighting colleagues and experts, for which a remote sensing would have been very helpful.

3. Results

In this study 9 rural fires were analysed, all of them can be found in the 2021 year database of the Hungarian Fire Service. These fires were marked with A, B and C with 1 – 3. Authors summarized the data of these fires in the Table 1, where the time of fire alarm (T_p – passive fire “detection” that is reported by civilians), the time when fire could have been detected by the webcam video (T_C – optional detection time) and the time of the beginnings of the suppression (T_A – arrival time of the fire service) were provided. Based on these data authors could calculate the time of the free escalation of the fires (t_{dfree}), the time of marching of the firefighters (t_m), the fire development time of the fire supposed in case of webcam analysis (t_{dcam}) and the obtained time in case of camera based detection (t_w). In this study 1 minute was added to the cases of camera based fire detection as processing time. Based on the above data authors calculated the rate of fire propagation in all cases of passive detection (v_{tp}) and took also an average rate of spread for the further calculation (v_f).

Table 1. Data of fires analysed in this study.

	A/1	**A/2**	**A/3**	**B/1**	**B/2**	**B/3**	**C/1**	**C/2**	**C/3**
T_P	18:55	16:33	14:20	15:13	13:56	17:04	15:49	14:41	15:37
T_C	18:45	15:34	14:09	14:05	12:44	16:50	15:18	14:36	15:25
T_A	19:19	16:51	14:47	15:47	14:13	17:24	16:14	14:50	16:18
t_{dfree} [min]	24	77	38	103	89	34	56	14	54
t_m [min]	14	18	27	34	17	20	25	9	41
t_p [min]	1	1	1	1	1	1	1	1	1
t_{dcam} [min]	15	19	28	35	18	21	26	10	42
t_w [min]	9	58	10	68	73	13	30	4	11
v_f [$mmin^{-1}$]	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
v_{tp} [$mmin^{-1}$]	3.3	2	1.8	0.7	2.45	1.65	1.78	4	1.8
A_p [m^2]	20,000	80,000	15,000	20,000	150,000	10,000	30,000	10,000	30,000
R_p [m]	79.8	159.6	68.1	79.8	218.5	56.4	97.7	56.4	97.7
K_p [m]	501	1,003	434	501	1,373	354	614	354	614
A_A [m^2]	10,747	5,489	11,921	18,626	4,926	6,705	18,626	1,520	26,822
R_A [m]	33	42	62	42	40	46	77	22	92
K_A [m]	207	262,6	387	483	248,8	290,3	483,8	138,2	580
K_d [m]	294	740	47	18	1,124	64	130	216	34
T_d [m^2]	9,253	74,510	3,079	1,374	148,876	3,295	11,374	8,480	3,178

Legend:

T_P : passive fire detection (fires, reported by civilians)	**v_{fp}:** assumed rate of fire spread based on passive detection
T_C: active fire detection (fires, can be seen on webcam)	**A_P :** burnt area at arrival in case of passive detection
T_A: arrival time of the first responders	**R_p:** the radius of the fire at arrival (passive detection)
t_{dfree} : time of fire escalation at real intervention	**K_p :** the perimeter of fire at arrival (passive detection)
t_m: marching time of first responders	**A_a :** burnt area at arrival (active detection)
t_p : assumed processing time of the automatic signal	**R_a :** the radius of the fire at arrival (active detection)
t_{dcam} : time of fire escalation according to the camera signal	**K_a :** the perimeter of fire at arrival (active detection)
t_w : time obtained by using automatic detection	**K_d :** the difference in the perimeter of fire
v_f : supposed rate of fire propagation	**T_d :** the difference in the area of fire

Database contains even the size of the burnt area reported officially by the firefighters after arriving to the fire front (A_P), and based on these the study calculated the radius (R_P) and the perimeter (K_P) of each fire. The authors also provided these data for webcam based active detections (A_A, R_A, K_A) and calculated the differences of the perimeter and the burnt area in case of each fire. The rate of the burnt areas in case of passive and assumed active detections presented in the Figure 1 as well as the time benefit between the passive and active detection.

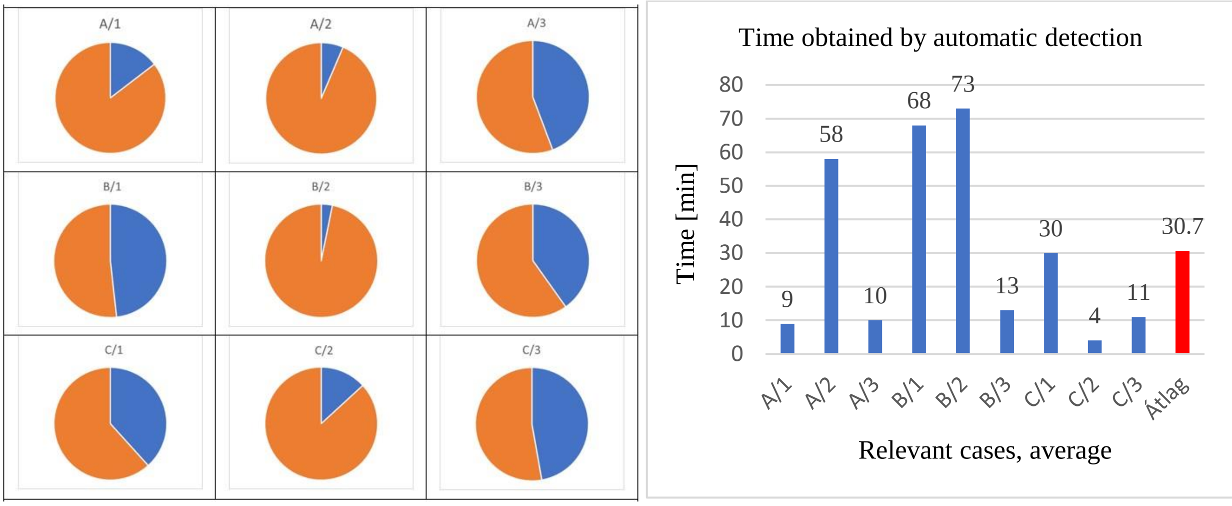

Fig. 1. The rate of the burnt areas in case of passive (orange) and active detections (blue) (left) and the time benefit between the passive and active detection (blue) with the average time benefit (red) (right). Created by authors.

Results show that in all cases using active detection firefighters would have had time gain, 4 minutes in the worst case (C/2) and 73 minutes in the best case (B/2), averagely more than 30 minutes (30.7 min). The burnt area would have been also smaller, with 1,374 m^2 in the worst case (B/1) and almost with 15 hectares in the best case (B/2), without the best case, averagely almost 1.5 hectares per fire. The perimeter, which is the fire front that firefighters have to suppress would have been shorter with 18 meters in the worst case (B/1) and more than 1 km in the best case (B/2), averagely 193 meters without the best case. Based on the above, authors state that the active fire detection can be effective even if fire service uses only the low-cost webcam solution for it.

4. Conclusions

It is very difficult to predict precociously the advantages of any early warning systems and camera based fire detection systems belongs to it too. Therefore, researches focusing on it have to take some simplifications and standard assumptions. This study generated by a random fire detection, however, authors could collect nine other cases to base the results. Even if this research focused on the saved area that can be achieved by the time difference between the traditional (reported by civilians) and camera based fire detection, authors found even some other results. One of these is, there was no fire to be reported earlier than staff could have been detected by cameras. All fires could be seen earlier by cameras than the fires was reported by civilians, averagely cameras could detect fire about 30 min earlier. The other is the standard deviation of the fire propagation is not essential in firefighters view; firefighters can calculate with 2.2 m/min fire propagation. Using surveillance cameras for fire detection can be a good opportunity in the future however more research is required to optimize its capability besides remaining even the original function. Summarizing the results, research demonstrates that, we can gain advantages even with a cheap and existing surveillance camera systems to reduce the burnt area.

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