Use of an Infrared Thermometer with Laser Targeting in Morphological Scene Change Detection for Fire Detection

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Abstract. Morphological Scene Change Detection (MSCD) is a process typically tasked at detecting relevant changes in a guarded environment for security applications. This can be implemented on a Field Programmable Gate Array (FPGA) by a combination of binary differences based around exclusive-OR (XOR) gates, mathematical morphology and a crucial threshold setting. This is a robust technique and can be applied many areas from leak detection to movement tracking, and further augmented to perform additional functions such as watermarking and facial detection. Fire is a severe problem, and in areas where traditional fire alarm systems are not installed or feasible, it may not be detected until it is too late. Shown here is a way of adapting the traditional Morphological Scene Change Detector (MSCD) with a temperature sensor so if both the temperature sensor and scene change detector are triggered, there is a high likelihood of fire present. Such a system would allow integration into autonomous mobile robots so that not only security patrols could be undertaken, but also fire detection.

1. Introduction
This continues on from the work presented in [1 – 4] inspired by [5 – 6], for various applications from intruder detection to the detection of leaky pipes. The hope being that this technology will be eventually incorporated into an autonomous mobile robot that could perform patrol duties as in [4]. Morphological Scene Change Detection (MSCD) previously developed was for the detection of intruders [3] and then the result was passed through a skin-filter in order to detect human facial features [4]. This version would now allow people to detect fire where it may not be feasible to place an ordinary smoke detector such as in building sites where the system is not yet in place, or on agricultural land to protect crops from fire during warm periods. Another application is to provide extra help for the elderly or disabled, a patrol mentioned in [7] could operate inside or outside a building and could detect fires that are not yet significant enough in magnitude to trigger a conventional fire alarm system, the aim being to stop criminals from praying on the venerable. As with previous work, this technology will be used to augment existing safeguards rather than replacing them and can be easily moved from location to location via the robot or a mobile platform.

Video surveillance systems with detection tasks usually include a module aimed at detecting relevant changes in a guarded environment [3, 5 – 6]. If the input to the Morphological Scene Change Detector (MSCD) module is pre-processed, it can improve the accuracy of the result; in this case a threshold is applied to the incoming greyscale image in order to remove unwanted intensity information to assist in extracting certain information from the scene. A similar process was carried out in [4] where the skin tone of the intruder was determined to assist in facial detection. By extracting features here that result
from a change due to a fire burning, this can be related to either a high intensity from the brightness of the flame or as the environment is consumed by the flames. The latter will result in the environment undergoing a shape change as the material burns, allowing for it to be picked up by original algorithm. As in the original system [3], the output of the MSCD circuitry should undergo a noise reduction filter to assist in removing any unwanted data, helping to improve the accuracy of the counting used to trigger the alarm system and compensate for any camera movement during the process. This will be done again using a combination of mathematical morphology [1].

Figure 1 shows the basic results of a simple situation, showing the reference image, the current image, the XOR difference between the two and the mathematical morphology to assist in cleaning away the noise from camera mismatch. The threshold setting is a crucial step because different threshold values provide extremely different results, in this situation, different thresholds will be experimented with in order to produce the optimum level with which to detect the flames when burning various materials. Using video for fire detection is not new [8 – 9]; various techniques have been used previously in order to detect flames whilst others focus on the smoke that they emit. In this situation however we will be augmenting the system with an infrared thermometer so that both visual information and temperature can be used as triggering mechanisms.

Fire is one the disasters that occurs in everyday life and causes losses in both terms of materials and life. In fire fighting, fires are identified according to one or more fire classes. Each class (Figure 2) designates the fuel involved in the fire, and thus the most appropriate extinguishing agent. The classifications allow selection of extinguishing agents along lines of effectiveness at putting the type of fire out, as well as avoiding unwanted side-effects. For example, non-conductive extinguishing agents are rated for electrical fires, so to avoid electrocuting the firefighter. Figure 2 shows a table of the different classes according to the American standard. “Ordinary combustible” fires are the most common type of fire, these occur when a solid, organic material such as wood, cloth, rubber, or some plastics become heated to their ignition point. At this point the material undergoes combustion and will continue burning as long as the four components of the fire tetrahedron (heat, fuel, oxygen, and the sustaining chemical reaction) are available. In this piece of work the main fuel sources will be
plastic, polystyrene, wood, paper, kerosene and vegetable oil, the latter two being classes B and K [10].

The remainder of this paper is structured thusly: Section II provides an overview of the adaptations to the previously designed systems; Section III discusses the simulation results and the triggering levels, whilst Section IV concludes the paper and discusses the future of this research.

| CLASSES OF FIRES | TYPES OF FIRES | PICTURE SYMBOL |
|------------------|---------------|----------------|
| A                | Wood, paper, cloth, trash & other ordinary materials. | ![Symbol A] |
| B                | Gasoline, oil, paint and other flammable liquids. | ![Symbol B] |
| C                | May be used on fires involving live electrical equipment without danger to the operator. | ![Symbol C] |
| D                | Combustible metals and combustible metal alloys. | ![Symbol D] |
| K                | Cooking media (Vegetable or Animal Oils and Fats) | ![Symbol K] |

**Figure 2.** The different classes of fire according to the American standards [10]

2. System Design

The system required very few modifications in order to make it into a flame detection system; these changes are shown in Figure 3 and 4. At the Register Transfer Level (RTL), very little modifications were required and these changes are highlighted in red. The red connection shows how the temperature sensor is added to the system; this is achieved by using a 10 bit unsigned data line that is connected to the “trigger_analysis” block, also highlighted in red. The remainder of this level remains the same as in the original system from [3]. Figure 4 shows the updated counter block at the gate level; here the temperature sensor data is connected to a comparator module. The comparator compares the incoming temperature against a value contained within the value tag set by the user, if the incoming value exceeds this, the output of the comparator is high, otherwise it remains low. The output from this comparator is then sent into an AND gate with the output from the image data trigger comparator, if both are high then the fire alarm mechanism is activated and sent out via a binary port.

**Figure 3.** The new RTL level for the system
3. Simulation Results

When undertaking the simulations, there were three cases to consider:

(i) From the reference image to the fire image (Figure 8)
(ii) Successive frames of fire images (Figure 5)
(iii) From the reference image before the fire to the image after the fire (Figure 6)

The first task was to set an appropriate thresholding level and as such different 8-bit thresholds were applied after the greyscale image had been input. The ranges considered ranged from 100 to 240 and these differences are shown on some example test data in Figure 7. As can be seen from figure (a), at the lower levels there is still a lot of noise in the image from camera mismatch which would interfere with the triggering mechanism and increase the number of false alarms. On the other hand, shown in figure 7b), when the level is set too high it begins to erode the image down too much and so for when the flame is not as obvious as in Figure 5, the flame data would be completely removed. The final threshold value to be used was selected to be 185.

When measuring the temperature data, it was found to range greatly from 90°C for paper at the start of its combustion to 340°C towards the height of its burning. The kerosene recorded the highest temperature using the sensor at 356°C at a distance of 5m whilst the body recorded a temperature of 21–35°C at various distances. Human body temperature was used as a control as the burning experiments took place outside and since the temperature varied from one session to the next, a control was required. As a result of these findings, the threshold for the temperature sensor was set to 150°C as nothing detected during the tests reached this temperature apart from the fire. If the environment does contain items above this setting, the temperature can be changed by modifying the value tag highlighted in Figure 4.

Figure 8 shows a complete series of tests and resultant images where an object is shown in its pre-burnt state and compared to when it is burning. This image was selected as the actual flame data is small and will provide a measure as to how accurate the system is. After the threshold and XOR gate was applied, the noise reduction filter was able to screen all of the unwanted information away and left just the flame data which is shown in Figure 8d). When all the data was analysed from the 3 different test cases for the 6 different combustibles, the most suitable lower threshold level was found to be 0.1% pixel change in the image. The images in these tests were 648 x 484 so that means that the trigger is set to 188 pixels and can be easily calculated for other image sizes. This can of course be set higher if the user is looking for a much more substantial sized flame.
**Figure 5.** Comparison between two successive frames of fire image (kerosene)

**Figure 6.** Comparison between before the fire and afterwards (plastic)

**Figure 7.** Different 8-bit greyscale threshold levels, (a) 100; (b) 240;
4. Conclusions
This paper has shown that it is possible to augment the Morphological Scene Change Detector to be able to detect the movement of a flame and additionally verify it by the use of a infrared temperature sensor. The system is accurate and can not only detect large areas of flame but relatively small ones too, which would be advantageous for if a fire has just started. The issue about pixel compensation for animals and wildlife outside is solved by the fact that the temperature sensor is present, this prevents small occurrences moving across the scene that may be a cat, dog or bird from triggering the system as it would not be warm enough to trigger the temperature sensor. Future work will now consist of combining this system will all the other MSCD based systems to form the core of the autonomous mobile robot software so that its construct can begin.

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