

## Section 1 Introduction

Fire has a major impact on the lives of human life and the environment [1][2]. Based on the average of fire cases in 39 countries from 1993 to 2017, there were 42,000 deaths per year caused by fire [3]. Traditional fire sensor assistance still has the disadvantage that certain fire particles must reach to the sensor first to trigger the alarm to sound. This can certainly slow down the process of detecting a fire, so this approach is considered less effective, especially if it is used in an open environment. To prevent the spread of fire as soon as possible, a system is needed that can detect fire at its earliest appearance. that can detect fire at its earliest stages. Currently, the application of digital image processing technology in fire detection has been widely developed. These technologies have a faster response time than traditional sensors. Paresh et al. [4] used a combination of Lab, YCbCr, and RGB color models for color segmentation of fire which resulted in an average experimental accuracy value of 80.98%. The proposed research works well on videos that have fire in them, but the accuracy value decreases when tested on videos that do not have fire in them. Gong et al. [1] performed fire detection by combining dynamic (motion and shape) and static (color) features of the fire. The combination method of RGB and HSI color models is used in extracting the color of the fire. The proposed algorithm produced good stability and a high accuracy rate of 95.29% in the final test results. However, the algorithm is prone to false alarms when there are red and moving objects. The object is colorfully different from the fire because the color of the object tends to be monotonous while the fire has a color with its own characteristics, so the use of a combination of RGB and HSI color models alone cannot produce optimal results for extracting the fire color. The combination of Lab, YCbCr, and RGB color models can extract well the color characteristics of fire whose illumination is high and whose colors range from yellow to red. This opinion is corroborated by Chen et al. [5] who used YCbCr color to detect the color of fire with the results of their research which had an F1-score of 97%. Thus, this research will use a combination approach of Lab, YCbCr, and RGB color models in fire color detection.

Based on the previous researches [1][4][5], this paper proposed a fire detection system using multi-feature fusion-based system that begins with an improved frame difference method and a combination of Lab, YCbCr, and RGB color models to eliminate nonmoving and nonfire pixels in video. The feature extraction is performed by calculating the boundary disorder of the fire with the convex hull, calculating the number of fire pixels in each frame to determine the variability of the fire area, and calculating the stability of the centroid. In the end, verification of the selected candidate fire images is done with support vector machine (SVM).