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AN OPTIMIZED SURF-BASED FIRE AND SMOKE DETECTION SYSTEM USING IMAGE PROCESSING FROM SURVEILLANCE VIDEO

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ABSTRACT

Over the last decades, digital image processing based fire and smoke detection have been improving steadily to provide a more accurate detection results in the area of surveillance security system. Detection of the fire and smoke from the surveillance videos is very challenging task due to the complex structural properties of the video frames or images and need improvisation in the existing work by utilization of feature selection or optimization approach to select on optimal feature according to the fire and smoke. A research based on the combination of various feature extraction techniques with feature selection approach for fire and smoke detection has been presented in this paper. In this research, we develop Fire and Smoke Detection (FSD) system using digital image processing with the concept of Speed up Robust Feature (SURF) along with the Intelligent Water Drops (IWD) as a feature selection and optimization algorithm. Here, Artificial Neural Network (ANN) is used as an Artificial Intelligence (AI) technique with that helps to select a set of optimal feature from the extracted by SURF descriptor from the video frames. By utilizing the concept of optimized ANN, the accuracy of proposed FSD system is increases in terms of detection accuracy and with minimum percentage of error. At last, the performance of the FSD system is calculated to validate the model and this shows that it is possible to use IWD with SURF as a feature extraction technique in order to detect the fire or smoke form the surveillance video with minimum error rate and the simulation results clearly show the effectiveness of proposed FSD system

KEYWORDS: Fire and Smoke Detection (FSD) System, SURF Descriptor, IWD Optimization, Artificial Intelligence (AI) and ANN.

1. INTRODUCTION

Due to the rapid developments in the world, the concept and usages digital technology [1] and their developments is also increases. Digital image processing and computer vision becomes one of the most useful area for developed world and it has lot of applications in the field of security, biometric, safety systems, medical imaging to remote sensing, industrial inspection to document processing, and nanotechnology to multimedia databases, etc. [2]. Video processing is the part of computer vision and today it is also in demand for the content based video processing such as object tracking anomaly detection, fire and smoke detection systems [3]-[4]. For the surveillance purpose, application of fire and smoke detection as tool has increase to due to the frequent occurrence of extended fire with consequences on human health and security but for the detection of fire and smoke generally electronics sensors are used [5]. So, the maintenance of electronic sensors is costly and always need a continuous power supply because the sensors are powered by a battery. To solve this type of traditional problem, we presents a model of Fire and Smoke Detection (FSD) System using the concept of image processing from surveillance video without using any electronics sensors. Main purpose to develop a FSD system is to solve out the electronics sensor based model because this type of model is only work for a certain condition and the chances of sensors damage is more in case of real fire and smoke [6]. To solve these problems, we designed a FSD system using the electronics surveillance cameras to capture the video. The block diagram of the proposed FSD system is shown in the Fig. 1.

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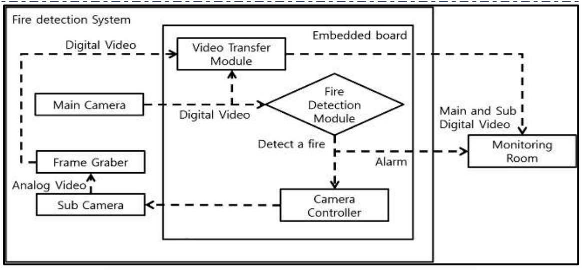

Fig 1: Block Diagram of FSD System

The block diagram of the proposed FSD system is shown in the above figure that depicts the entire procedure of the FSD system. The main surveillance camera is an installed at a fixed place and capture the real time video that helps to detect fire and smoke while monitoring video by utilizing the concept of image processing. After that all procedures are performed using the digital image processing algorithm [7]. Computer vision based FSD systems generally make use of three characteristic features of fire and smoke:

- Detect color of video frames
- Detect motion in video frames
- Geometrical feature

The proposed FSD system offer several foremost advantages over those traditional or sensor-based FSD system. Some advantages are given as:

- *Main advantage is the designing cost of digital image processing-based FSD system is cheaper and the easy to implement as compare to the FSD system.*
- *Proposed FSD system response time to detect the fire and smoke is faster compare to any other traditional FSD systems*
- *Developed FSD system has the ability to monitor a large area depends on the camera used but traditional FSD have limit to monitor the area.*
- *The most benefit of FSD system is the fire source is saved in a form of frames or images or videos which can used for promoting the expansion of the FSD system greatly.*

Basically, in this research article, we focus on the development of a FSD system using the concept of the digital image processing algorithm with the optimized Speed up Robust Feature (SURF) by Intelligent Water Drops (IWD) optimization algorithm that is a recently proposed as a meta-heuristics by Shah-Hosseini in 2007. Here, Artificial Neural Network (ANN) is used as classifier to train the FSD system by using fire and smoke optimized feature sets form the video frames and the significant contributions in this research are as following:

- We presents literature survey about the existing digital image processing based FSD system to find out the inferences drawn.
- Pre-processing steps are used to extract the frame from the surveillance video for the analysis.
- To extract feature from extracted frames of video, image, SURF descriptor is used with IWD as a feature optimization or selection approach.
- For detection of the fire and smoke from video, ANN is used as an Artificial Intelligence method.
- To validate the efficiency of proposed FSD system, comparison with existing state-of-arts is done in terms of Precision, Recall, F-measure, Accuracy, Execution Time and Error Rate.

We introducing the basic concept behind the proposed FSD system in this section of research article and the remaining paper is drafted as follows. In Sect. 2, literature survey about the existing digital image processing based FSD systems are described and whereas, the materials and methods are described in the Sect. 3. We presents the experimental results of FSD system in Sect. 4 and overall conclusion with the future possibilities about the FSD system is described in the Sect. 5.

2. RELATED WORK

In this section, we presents a brief survey on the existing fire or smoke detection models to find out the issues related in the detection of fire or smoke from surveillance video capture by cameras. In 2010, ***N. K. Fong*** presented survey on the automatic fire detection model problem where the problem which is faced during fire detection is

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mentioned [8]. The problem is mostly focused on the false alarm which leads to wastage of fire brigade resources. They analyze the mode based on the Time of day adjustment, Time delays, Multi-sensor, Use of multi-signature, Fuzzy Logic and Neural Networks. Before this survey, ***Majd Buhrepour et al.*** in 2009 presented a research on use of artificial intelligence techniques for residential fire detection in wireless sensor networks (WSNs) [9]. They perform a comparison with the NIST dataset using Feed Forward Neural Network, Naïve Bayes and Distributed Fuzzy Logic Engine where Naïve Bayes achieved the highest accuracy of 100%. After that in 2010, ***Majid Bahrepour et al.*** also improve the presented work on fire data analysis by utilizing the concept of feature reduction using computational intelligence methods [10]. Further work was conducted where comparison of three different classifier models that are Feed Forward Neural Network, Naive Bayes and Decision Tree are done on the residential fire dataset. Decision Tree achieved the highest accuracy of 99.08% when combination of four types sensors are used that are Temperature, Ionization, Photoelectric, and Carbon Monoxide (CO) Gas. ***C.Cainia et al.*** in 2011 presented a research on fire detection method using the concept of neural networks [11]. They introduce the model and compare the simulation results with expected values using Radial Bias Function Neural Network also called as RBFNN where the values achieved for error probability, smoldering fire and no fire was 2.3%, 1.8% and 1.0%. ***R. Divya et al***. in 2012 had conducted a research on fire detection system using the concept of digital image processing and artificial intelligence techniques [12] and they also used the RBFNN in which the network was trained with color space values so that fire can be detected through segmentation process. ***K. Angayarkkani et al.*** in 2010 also already presented a research on an intelligent system for effective forest fire detection using spatial data where RBFNN was tested on digital images of forest fire [13]. They used the concept of the image segmentation process, the image is first converted from RGB to XYZ color space and then anisotropic diffusion was applied to identify the fire region. ***Yongming Bian et al.*** in 2018 had conducted a latest research on the fire detection algorithm based on Tchebichef Moment Invariants (TMI) and Paritcle swarm optimization PSO along with the Support Vector Machine (SVM) where a novel algorithm was proposed for fire detection [14]. The propose hybrid algorithm was tested on the data which contains a series of images taken by a video camera. In first experiment, proposed model achieve achieved the highest detection rate of 98.18% but some cases detection rate decrease and observe near to 82.35% and the proposed mode is only applicable for fire not for smoke

So, in this research, we try to solve the existing problem by utilizing the concept of SURF as feature descriptor along with the IWD as selection technique with ANN to train and detect the fire or smoke from surveillance video.

3. METHODS & MATERIALS

In this research article presents a FSD system that is based on a computer vision to detect the fire and smoke using their feature to reduce the rate of false alarms and to increase the reliability of conventional FSD system. Meanwhile all the implementation of the proposed system need to cover the important places with CCTV security surveillance systems and capture the video, the proposed algorithm can be easily incorporated into a surveillance system monitoring indoor area of interest for early detection of fire and smoke. So, in this research, we proposes fire and smoke detection in a recorded video for the simulation purpose by analyzing the captured frame from the video by a normal camera. The structure of proposed FSD is briefly described and explained in this section that is based on the ANN as an artificial intelligence or classifier. The entire methodology of proposed FSD system is dived into two different phases named as Training and Testing phase. The brief details about both phases are given in the below section of this paper and Fig. 2 show the flowchart of both phased of the proposed FSD system.

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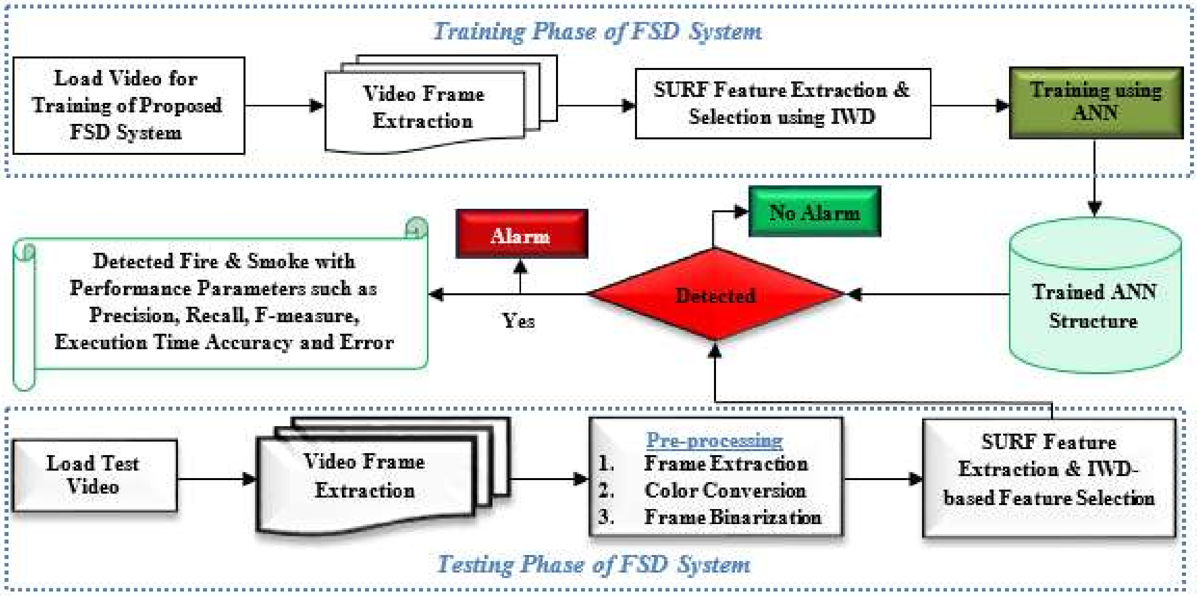

Fig 2: Flowchart of FSD System

The procedural and working steps of FSD system with surveillance videos is described in this section of research article according to the above shown flowchart in the Fig. 2. We use different steps like pre-processing, SURF feature extraction and selection using IWD technique with novel fitness function and ANN as classifier is sued to train the detect the fire or smoke from the surveillance videos. The subsequent steps demonstrate the variety of phases that need to be accomplished in the development of proposed FSD system and the used steps are given as:

Step 1. To design a framework of the proposed FSD system using the concept of Graphical User Interface that is known as GUI in MATLAB 2016a software and the developed FSD system interface is shown in the Fig. 3.

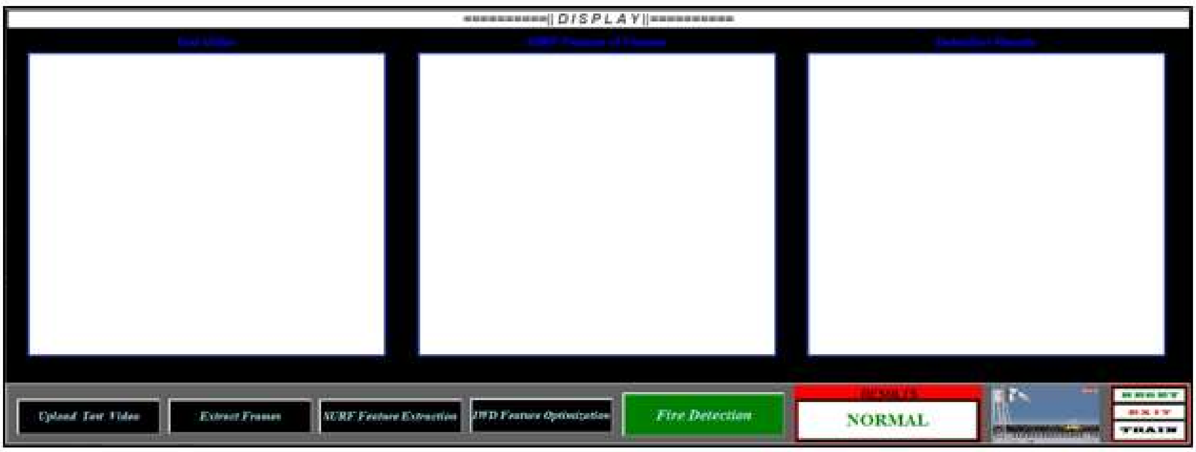

Fig 3: Proposed FSD System

Step 2. Upload test surveillance video with fire or smoke for the simulation of proposed FSD system. The frame of uploaded video of fire or smoke is shown in the Fig. 4. We only show a single frame of video because live video representation is not possible in the research paper.

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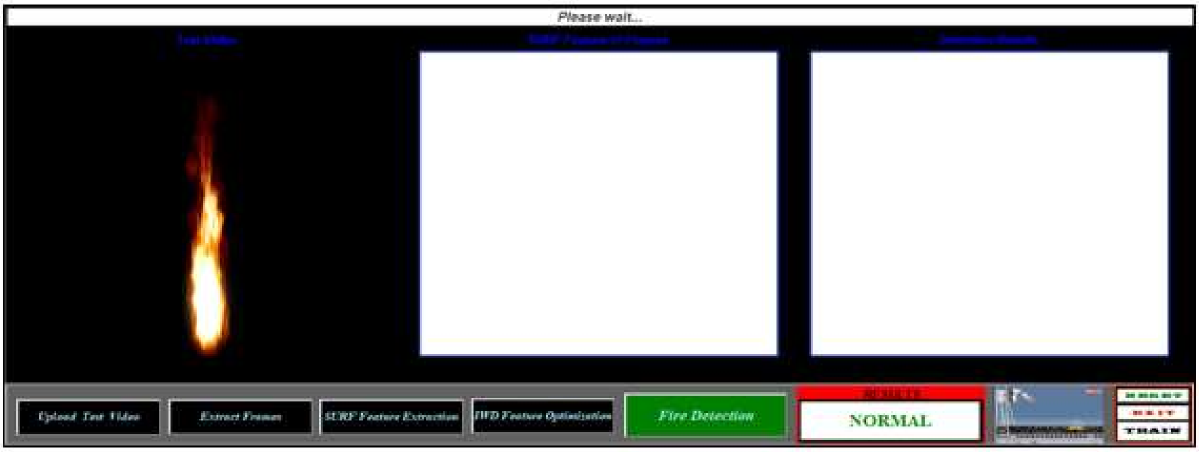

Fig 4: Uploaded Test Video in FSD System

Step 3. Apply pre-processing on the uploaded test surveillance video to extract the frames and also to make compatible frames for FSD system and SURF feature descriptor with optimization approach is used to select a better set of the features from the frame data with fire and smoke. Firstly, we extract frames, then apply the color conversion into grey level image and binarization to find out the exact region of fire and smoke in the frames. The algorithm of pre-processing for surveillance video is written as:

Algorithm 1st: Pre-processing on Video	
Input	V←Uploaded surveillance video
	Folder←Location of folder to store extracted frames from video
Output	Frames ← Extracted video frames
Steps	***Start Pre-processing***
1)	Set F_{COUNT} = 0 // Frame count
2)	**While has Frame (Video)**
3)	F_{COUNT} = F_{COUNT} + 1
4)	Frames = Read-Frame (V)
5)	Frames = Convert color (Frames)
6)	Frames = Binary (Frames)
7)	Save to Frames with F_{COUNT} in Folder using location
8)	**End – While**
9)	**Return:** Frames for uploaded video
10)	**End – Algorithm**

Step 4. When pre-processing is done, then we apply the SURF descriptor to extract the feature set from the region of fire or smoke and then IWD is applied with the fitness function according to the requirement for the appropriate feature selection, so we can find out the relevant set of feature for proposed FSD system. The algorithm of SURF is written as:

Algorithm 2nd: SURF Descriptor	
Input	Frames ← Extracted video frames
Output	F-points ← SURF feature points
Steps	***Start Feature Extraction***
1)	Calculate size, [R, C] = size (Frame)
2)	**For m = 1→ R**
3)	**For n = 1→ C**
4)	Scaling = Frame (m, n, 8) // Scaling of frames into 8 X 8

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5)	Ext_Det = Extrema (Scaling(I, J)) // detect extremes of scaled frame
6)	F-points = Localization (Ext_Det (m, n))
7)	Check: F-points orientation = F-points vary or not
8)	**If Variation occurs**
9)	Discard F-points
10)	**Else**
11)	F-Points = F-points (m, n)
12)	**End – If**
13)	**End – For**
14)	**End – For**
15)	**Return:** F-points as a set of extracted SURF feature points
16)	**End – Algorithm**

Using the above written algorithm of SURF descriptor, the extracted feature of the video frame is shown in the Fig. 5 with the sample grey level frame.

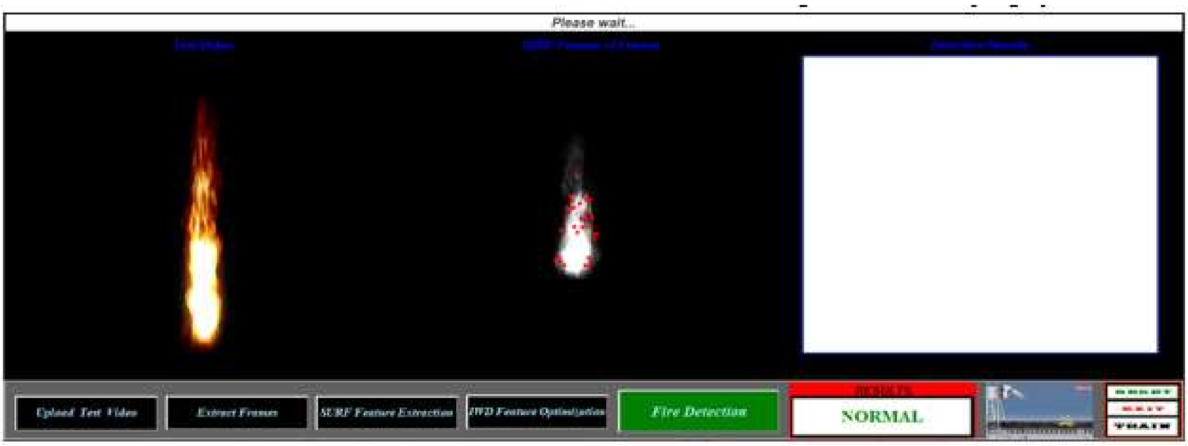

Fig 5: SURF Feature Extraction form the Frames in FSD System

Step 5. After the feature pattern extraction from the video frame using SURF descriptor, we use the concept of feature section using the IWD as a method of optimization and the algorithm of the IWD algorithm is written as:

Algorithm 3rd: Feature Selection using IWD	
Input	F-points ← SURF feature points
	MAX_{ITR} ← Maximum iteration
	Pop ← Number of populations
	FF ← Fitness Function of IWD
Output	OF-points ← Optimized feature points
Steps	***Start Feature Selection***
1)	Set $FT_{COUNT} = 0$ // Feature count
2)	**Call FF,** $F(f) = \begin{cases} 1\ (True); & if\ F_s \geq F_t \\ 0\ (False); & Otherwise \end{cases}$
3)	**While ITR = MAX_{IRT}**
4)	$FT_{COUNT} = FT_{COUNT} + 1$
5)	F_S = F-points (ITR)
6)	F_t = mean (F-points)
7)	OF-points = IWD (F_s, F_t, Pop, FF)

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8)	**End – While**
9)	**Return:** OF-points as a set of optimized feature points
10)	**End – Algorithm**

Step 6. Initialize ANN for fire and smoke detection purpose using two phases, namely, training and testing. After the training, save the trained structure which used in the detection section to detection the fire and smoke from the surveillance video. The used ANN algorithm is written as:

Algorithm 4th: ANN for FSD System	
Input	OF-points ← Optimized feature points
	Group ← Fire and Smoke
	N ← Number of Neurons
Output	FSD-Structure→ Trained structure with Detection Results of FSC System
Steps	***Start Training***
1)	**Initialize the basic parameters of ANN** –Number of Epochs (E) –Number of Neurons (N) –Performance: MSE, Gradient, Mutation and Validation –Techniques: Levenberg Marquardt – Data Division: Random
2)	**For i = 1 → OF-points**
3)	**If OF-points ε Fire** Group (1) = Features (OF-points)
4)	**Else if OF-points ε Smoke**
5)	Group (2) = Features (OF-points)
6)	**Else // Extra**
7)	Group (3) = Features (OF-points)
8)	**End – If**
9)	**End – For**
10)	Initialized the ANN, **Net = Newff (OF-points, Group, N)**
11)	**Net = Train (Net, OF-points, Group)**
	Detection of Fire & smoke
12)	Test Frame = Simulate (Net, OF-point of Test Frame)
13)	**If Matched with Fire or Smoke**
14)	Detected and alarm
15)	**Else**
16)	Normal
17)	**End – If**
18)	Calculate Parameters
19)	**Return:** Detected Results with detection Parameters
20)	**End – Algorithm**

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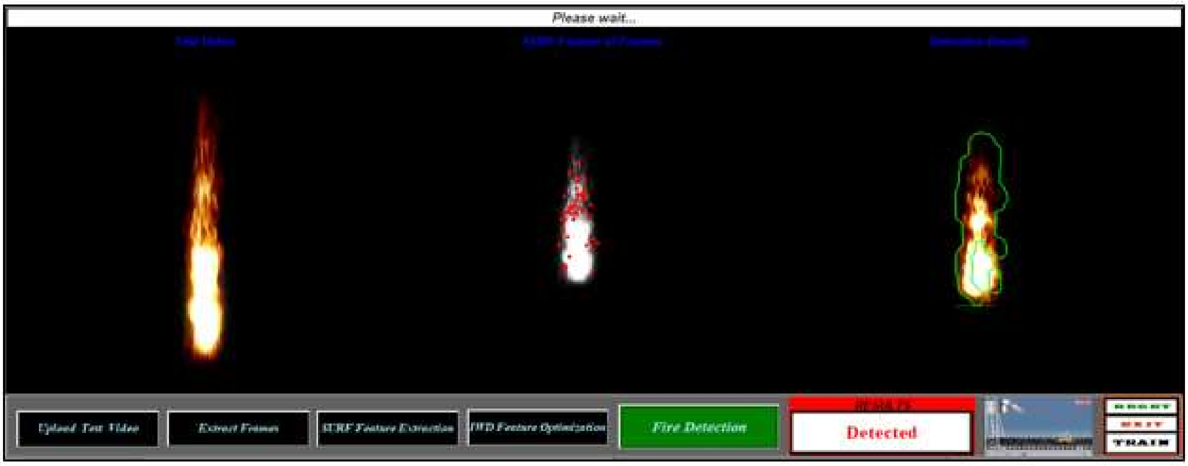

Fig 6: Fire Detected in FSD System

Step 7. At last of simulation, the performance parameters of proposed FSD system is calculated in terms of Precision, Recall, F-measure, Accuracy and Execution Time.

The simulation results analysis of the propose FSD system is discussed in the next section of this research article with the comparison to validate the system efficiency.

4. RESULTS AND ANALYSIS

In this section of research article, we describe the simulation results of the proposed FSD system to detect the fire and smoke from the capture video using the surveillance camera. So, the proposed FSD system is test on the own dataset of the surveillance video for the fire and smoke based on their optimized SURF features using the ANN as a detection approach. Finally, the validation of prosed FSD system carried out to evaluate the model based on the 10 different surveillance video. Based on the quantities parameters such as True Positive (TP), False Positive (FP), True Negatives (TN) and False Negative (FN), we evaluate the effectiveness of the proposed FSD system using some quantities contexts parameters like Positive Predictive Value (PPV) or Precision, Sensitivity or Recall and there harmonic means that is known as the F-measure with Accuracy and Execution Time to detect the fire and smoke from the surveillance video. The Precision is computed using the given equation:

$$Precision = \left|\frac{TP}{TP + FP}\right|$$

For the better efficiency of the FSD system, PPV or Precision should be more and also Sensitivity or Recall is one of the most affective parameters and the Sensitivity or Recall is computed using the given equation:

$$Recall = \left|\frac{TP}{TP + FN}\right|$$

To ensure the performance of our proposed model, we used the F-measure to compute the overall efficiency of the system. We know that the F-measure is the harmonic mean of Precision and Recall that is used in the data retrieval system. The F-measure is also known as F-score or H-mean and it is computed using the given equation:

$$F - measure = \left|\frac{2 \times (Precision \times Recall)}{(Precision + Recall)}\right|$$

Accuracy is the overall FSD system performance measurement method and to calculate the system accuracy, we use the written equation:

$$\text{Accuracy} = \left|\frac{TP + TN}{TP + TN + FP + FN}\right|$$

One more parameters that is the execution time is also an important parameter that represents the system detection time of fire and smoke from the surveillance video using the concept of the optimized SURF feature based system and we hope the FSD system can performed better as compare to the sensor base FSD system. The simulation results of the proposed FSD system using the digital image processing techniques is given in the Table I and their graphical representation is also described in the below section of the research article.

Table I. Evaluation of FSD System Performance Parameters

Sample Images	Precision Rate	Recall Rate	F-measure	Error (%)	Accuracy (%)	Execution Time (s)
1	0.978	0.822	0.893	3.55	96.45	15.274
2	0.985	0.915	0.948	4.27	95.73	16.075
3	0.973	0.827	0.894	2.35	97.65	17.699
4	0.997	0.933	0.963	5.46	94.54	19.392
5	0.953	0.817	0.879	7.75	92.25	18.023
6	0.987	0.913	0.948	9.27	90.73	17.191
7	0.978	0.892	0.933	6.83	93.17	18.563
8	0.976	0.864	0.916	2.57	97.43	16.804
9	0.988	0.912	0.948	4.06	95.94	15.578
10	0.972	0.898	0.933	3.37	96.63	16.858
Average	**0.978**	**0.879**	**0.925**	**4.95**	**95.05**	**17.14**

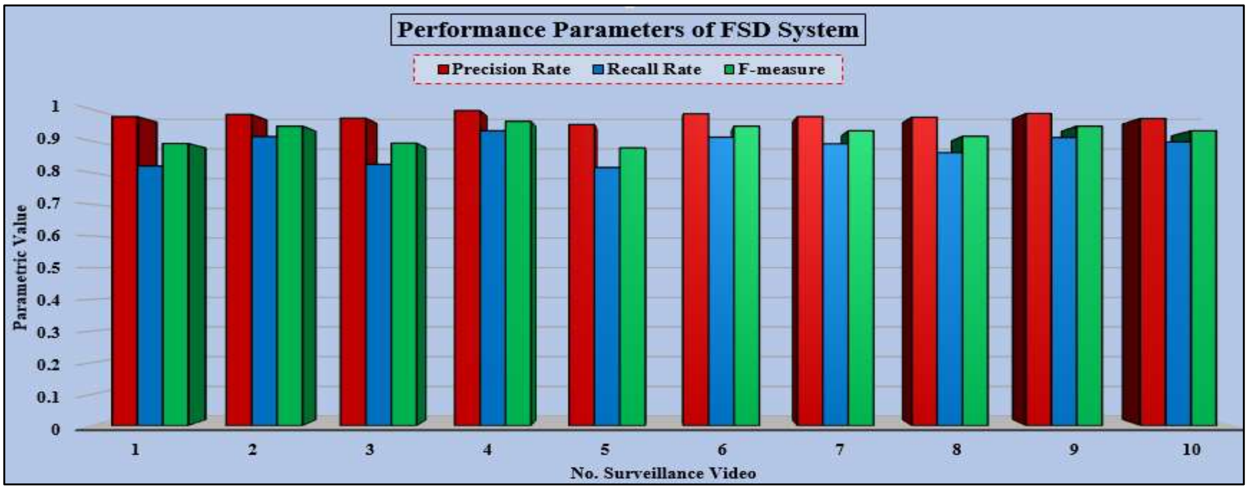

Fig 7: PRF of FSD System

Above simulation results based on the 10 sample surveillance video is given in term of PRF (Precision, Recall and F-measure) for the FSD system and the accuracy and error of the system show that the system have its own impact in the era of fire or smoke detection using the image processing using the optimized SURF feature in with artificial intelligence technique.

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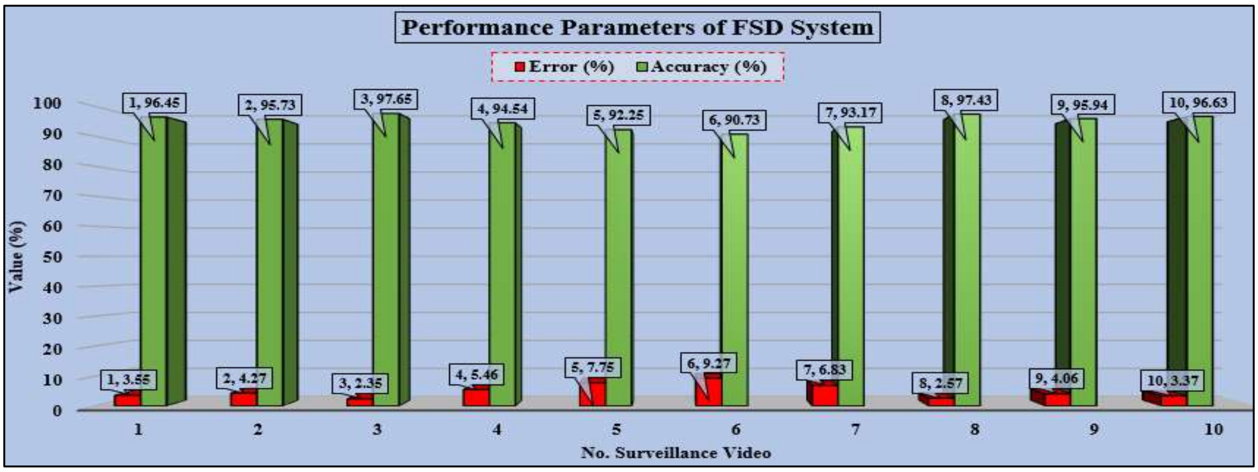

Fig 8: Error and Accuracy of FSD System

Above figure represents the fire or smoke detection accuracy and error rate of proposed FSD system and we observed that the accuracy of system is higher by utilizing the concept of digital image processing instead of the sensor based model but for validation of model, we need to compare the results of proposed system with exiting work. So, we compare the simulation results of proposed mode with existing work proposed by ***Yongming Bian et al.*** [14]. The comparison of proposed FSD system with existing work is shown in the Fig. 9 with Table II based on the accuracy of system.

Table II. Comparison of FSD System

	Accuracy (%)
Yongming Bian et al. [14]	93.78
Proposed FSD System	95.05

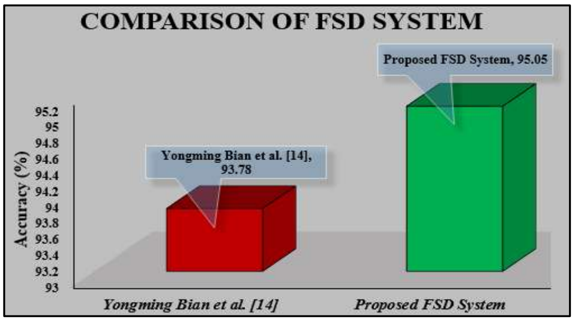

Fig 9: Comparison of FSD System

Based on the comparative analysis of the existing work with proposed FSD system, we observed that the accuracy of the proposed model is far better than the exiting work and it is possible by utilizing the concept of optimized SURF feature descriptor along with ANN and it show that the effectiveness of IWD optimization technique helpful for the feature selection with ANN to detect the fire or smoke from the surveillance video.

5. CONCLUSION AND FUTURE WORK

In this paper, an optimized surf-based FSD system using image processing from surveillance video. We have evaluated whether it is possible to use optimized SURF feature set in order to minimization of error rate in the proposed FSD system with IWD based feature selection and optimization. We showed that, it is possible to make an automatic fire or smoke detection by utilizing the IWD-based SURF feature along with the ANN as a classifier, which takes input as SURF feature sets to train the FSD system and we trained the model based on the different surveillance videos. From the simulation analysis of experimental results, we observed that the proposed FSD

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system is an innovative and successful steps towards the fire or smoke detection using the digital image processing instead of the sensor based model. In future, proposed FSD system could be designed behalf of the concept of hybridization of different swarm intelligence approaches to detect fire or smoke with initial stage.

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