FIRE DETECTION USING VIDEO ANALYTICS

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Introduction

- Fire causes severe damages
- Prevention of accidents is crucial
- Fire detection using computer vision
- Part of a larger surveillance system

Problem Definition

To identify algorithm, implement all modules and related software in production and all post- implementation tasks related to the fire detection system.

The main tasks for the project execution are

1. Identification of various algorithms for fire detection
2. Compare the algorithms and identify best approach
3. Implement the selected algorithm in platform independent C code

Traditional Fire Detection Systems

• Sensors - high false alarm rate

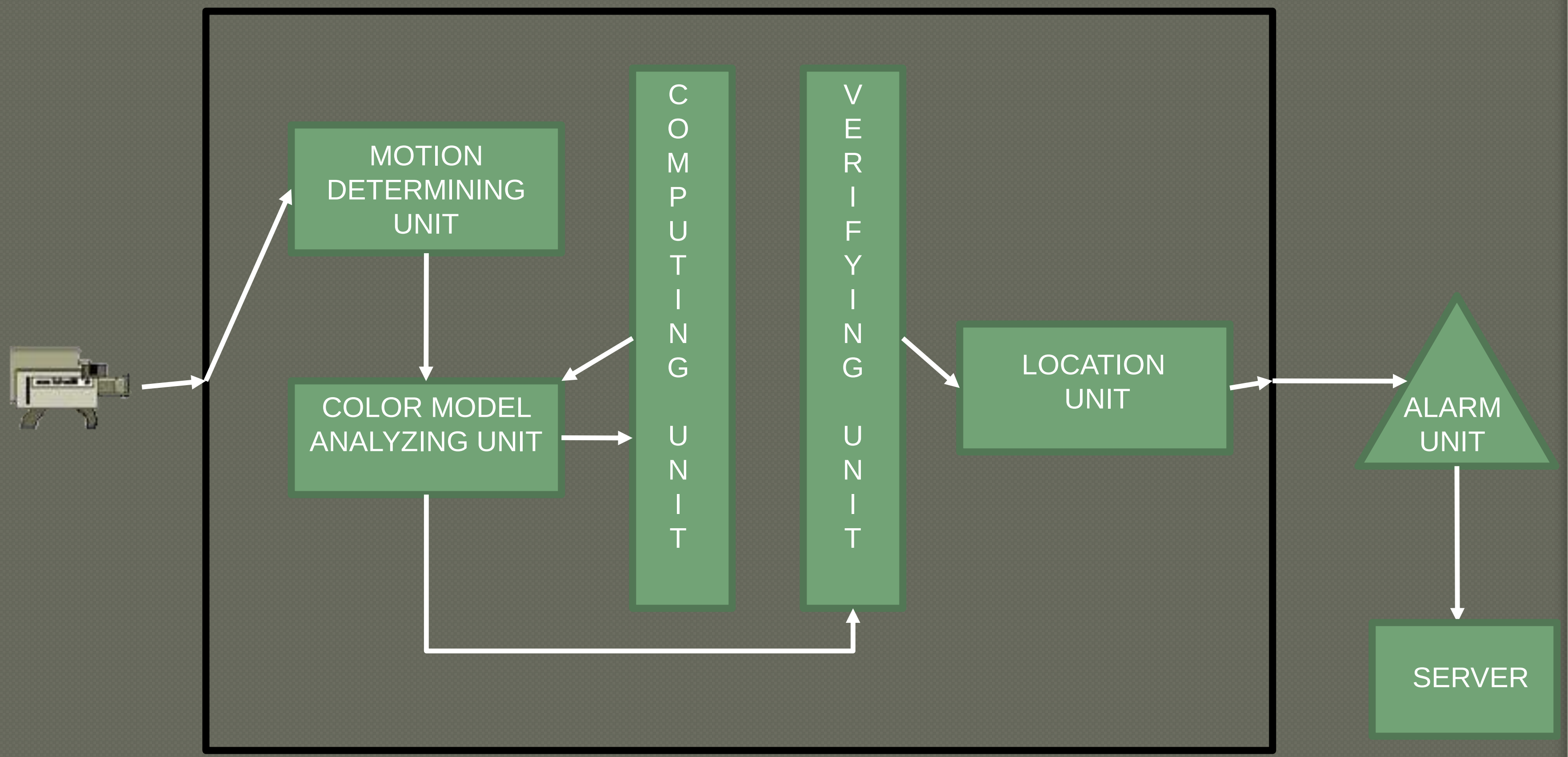
•Open and large areas- not suitable

•Fatal time delays

•Detects smoke not fire

•Higher density for greater precision

Design



MOTION DETERMINING UNIT
COLOR MODEL ANALYZING UNIT
COMPUTING UNIT
VERIFYING UNIT
LOCATION UNIT
ALARM UNIT
SERVER

Modules

- **Motion Detecting Unit**
  - Compare frames
  - Detect moving objects

- **Color Model analyzing Unit**
  - Identify Intensity
  - Use RGB/HSV Model
  - Compare with threshold value

- **Computing Unit** (DSP for Image Processing)
  - Edge Detection
  - Fire Pattern Detection

- **Verifying Unit**
  - Advanced algorithms
  - Test Different Cases

- **Location Unit**
  - Determine the exact location of Fire

- **Alarm Unit**
  - Blows Alarm on Fire
  - Affected area might be cut off.

Motion Detecting Unit

- **Create Fire and Non Fire databases**
  - Fire database-red component of pixels
  - Non fire pixel-background pixels

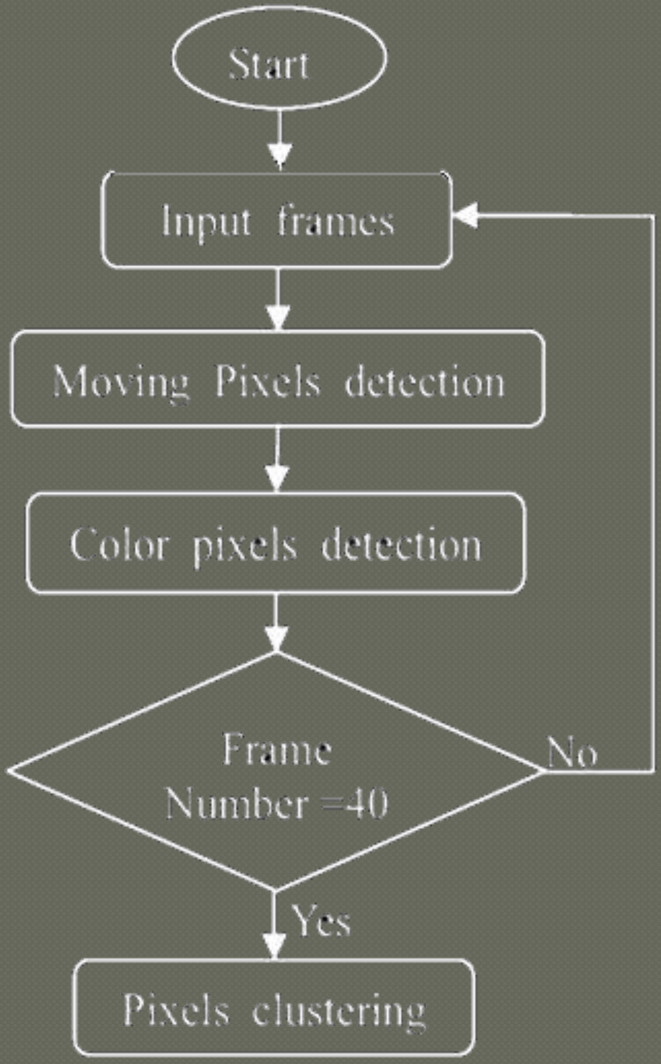
- **Candidate area selection**
  - **Moving pixel detection**
    - $h_t(X,Y)=\{f_t(X,Y) + f_{t+1}(X,Y) + f_{t+2}(X,Y)\}/3$
    - $DIFF(X,Y)=\{h_{t+1}(X,Y)-h_t(X,Y)\}$
  - **Fire Color pixel detection**
  - Rule 1: R>G>B
  - Rule 2: $R> R_t$
  - Rule 3: $S >=(255-R)*S_t/ R_t$

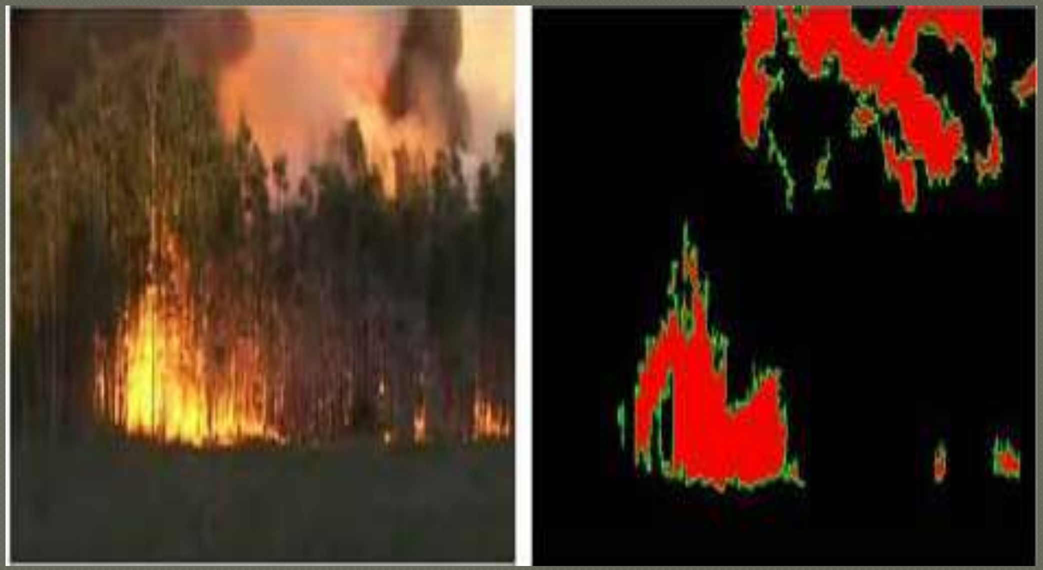

Original image


Result of Moving pixel Detection


Result of Fire Pixel Detection

Pixel Clustering





Various Approaches to Our Problem

- Different Approaches towards VISUAL FIRE DETECTION

  - Color-Based Approaches
    - RGB
    - HSV

  - Fire Feature based Approaches
    - Temporal
    - Spatial
    - Flickering
    - Energy variation

  - Motion based Approaches

Fuzzy Finite Automata

Introduction to FFA

- Fuzzy logic : a very efficient method for handling imprecision: an intrinsic property of Fire.

- Combines the capabilities of automata with fuzzy logic.

- Fits best in applications where the variables are continuous and/or mathematical models are difficult to define.

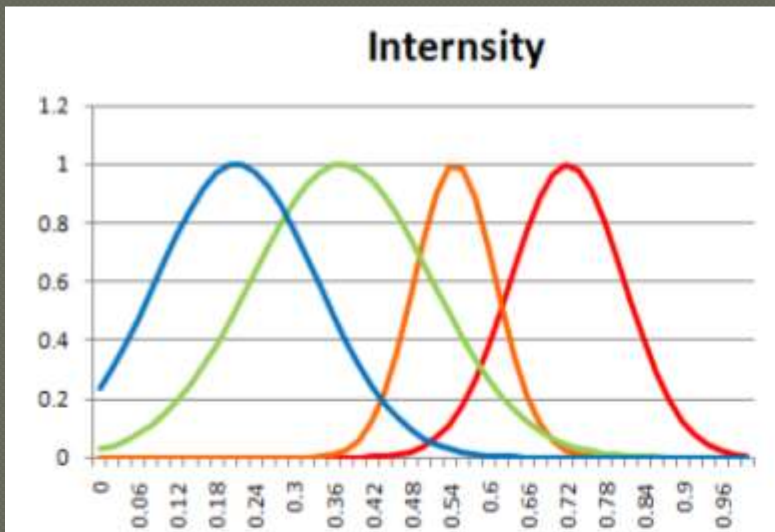
A FFA for flame verification is a 6-tuple denoted as:

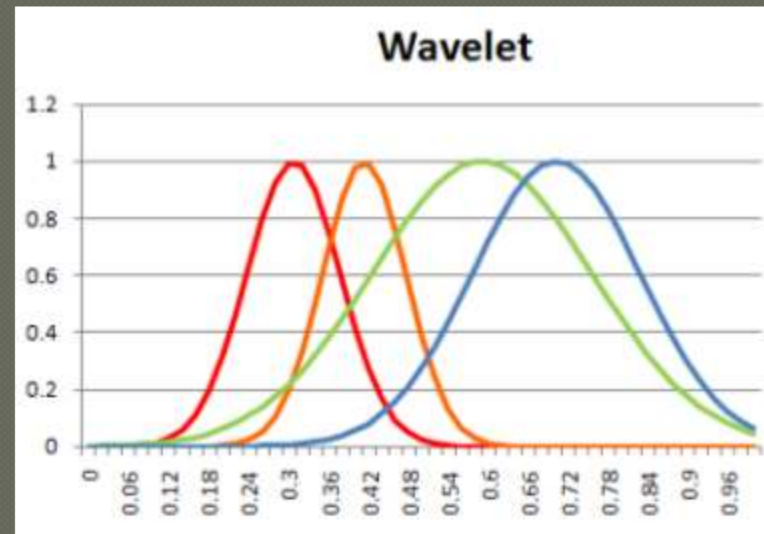
- F ={ Q, Σ, δ, R, Z, ω }
  - Q ={ VH, H, L, VL} is a finite set of states
  - Σ is a finite set of input symbols (events),
  - R={ VH } is a set of initial state.
  - δ: Q X Σ X Q →[0,1) used to map a current state into next state upon an input symbol
  - Z:output symbol {accept(Fire) , reject (Non Fire)}
  - symbol
  - ω: Q→Z : Output function for mapping a state to
  - the output set.

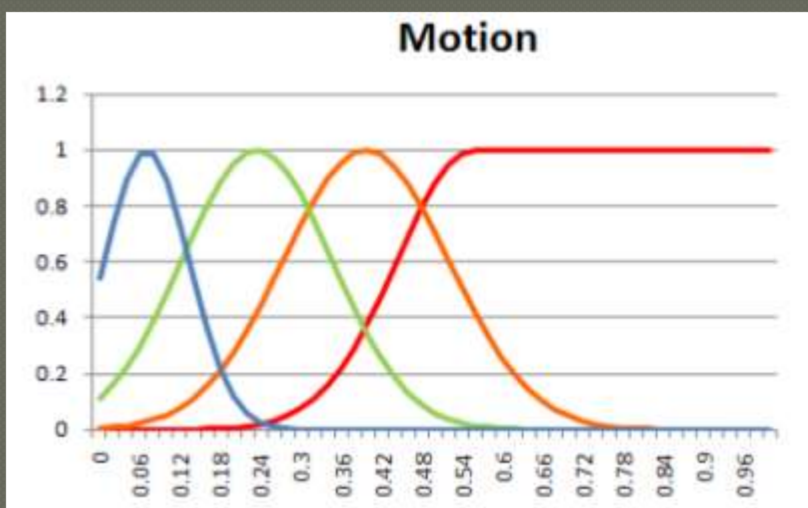
Fire-Flame Detection based on Fuzzy Finite Automation

- Variance of visual features extracted and probability membership functions generated for states.
- To assign MV of current state to next state, weighted average of transition functions taken.
- Fuzzy membership functions can have different shapes depending on the application and user preference.

Variation of Membership Functions







- Mean m_k = Mean (μ_{I_k} , μ_{W_k} , μ_{M_k})

Advantages

- FFA can model vague and uncertain information of flames.
- More robust to fast expanding flames with dynamic colors.
- Flexible choice of model architecture & membership functions of features.

Hidden Markov Model

Evaluation maximization Algorithm

- Evaluate Matrices-Fire and Non Fire database
- Evaluates similarity
- Apply viterbi algorithm-evaluate similarity
- Compare fire HMM with non fire HMM
- If Fire HMM>Non Fire HMM then
- Fire
- Else
- Not Fire

- Π - Initial state distribution
- A ij –State transition probability matrix
- B ij – Symbol probability distribution matrix

Hidden Markov Model

HMM Training

- Database Input data -> states(F1,F2,NF)

Algorithm

Input: C(i), C(i-1), State(i-1).   //c(i)-color values, i-current state pixel
Output: State(i).

if Current Pixel is not a moving pixel;
State(i)=NF;
else if State(i-1) is NF;
State(i)=F1;
else if |C(i)-C(i-1)| < th1;
State(i)= State(i-1);
else if |C(i)-C(i-1)| < th2;
State(i)= State(i-1);
else State(i)=NF;
End of Algorithm 1

Hidden Markov Model

- Previous work
  - Color Information
  - Shape Information
  - Wavelet Transformation

These approaches focus on **spatial** information

- Markov Model
  - Describes Temporal changes
  - Uses Flickering characteristic of fire
  - Fixed detecting point at the boundary of flame

METHOD

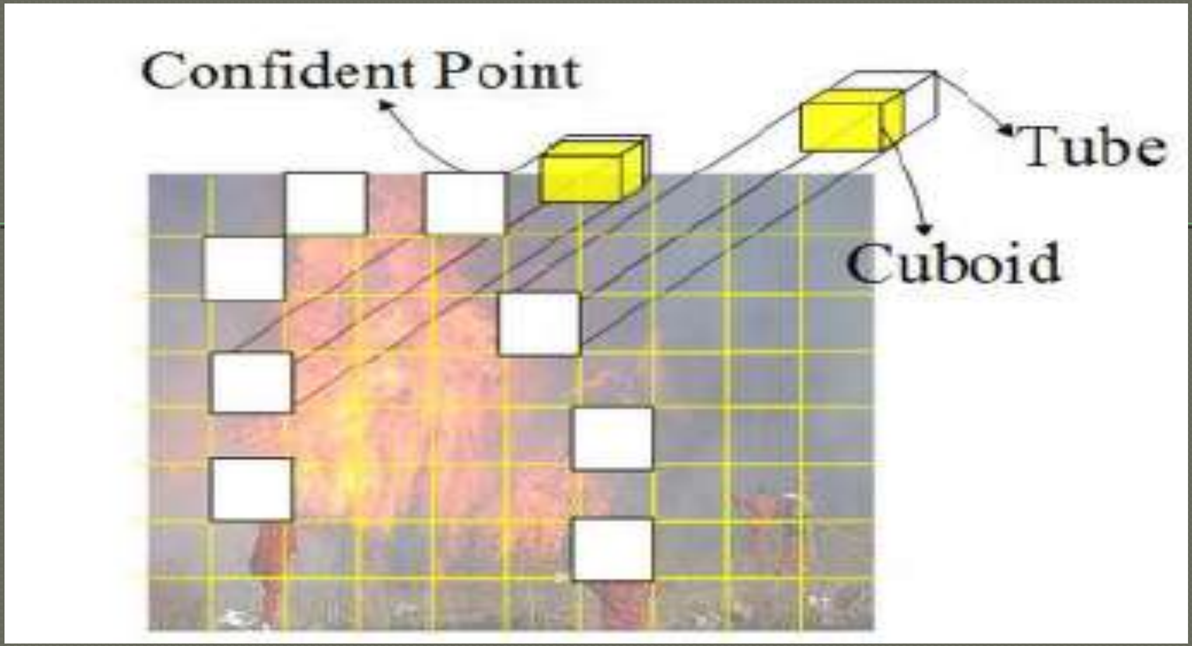
- Arrangement of Confident Points
  - Local 2D region along the flame boundary (R_i)
  - Calculate Confident value

$$\xi_i = \begin{cases} 1 & , R_i \textit{ is a flame point}, \\ 0 & , R_i \textit{ is not a flame point}. \end{cases}$$

$$K = \sum_{i=1}^{L} \xi_i$$

L is the number of detecting points.

  - If K/L > ς (a confident Threshold) then the region is a fire region.



- Spatio-temporal pattern features
  - Video considered as volume **V**
  - Local CPs as a tube **T**
  - Each Tube segmented into cubes Ci
  - Two channel wavelet decomposition for each region

Flame Flickering model by HMM

- Tubes from fire video samples are chosen
- Observation sequences are trained
- Three hidden states by k-means clustering
  - High Frequency state
  - Medium Frequency state
  - Low Frequency state
- Mixture of Gaussian

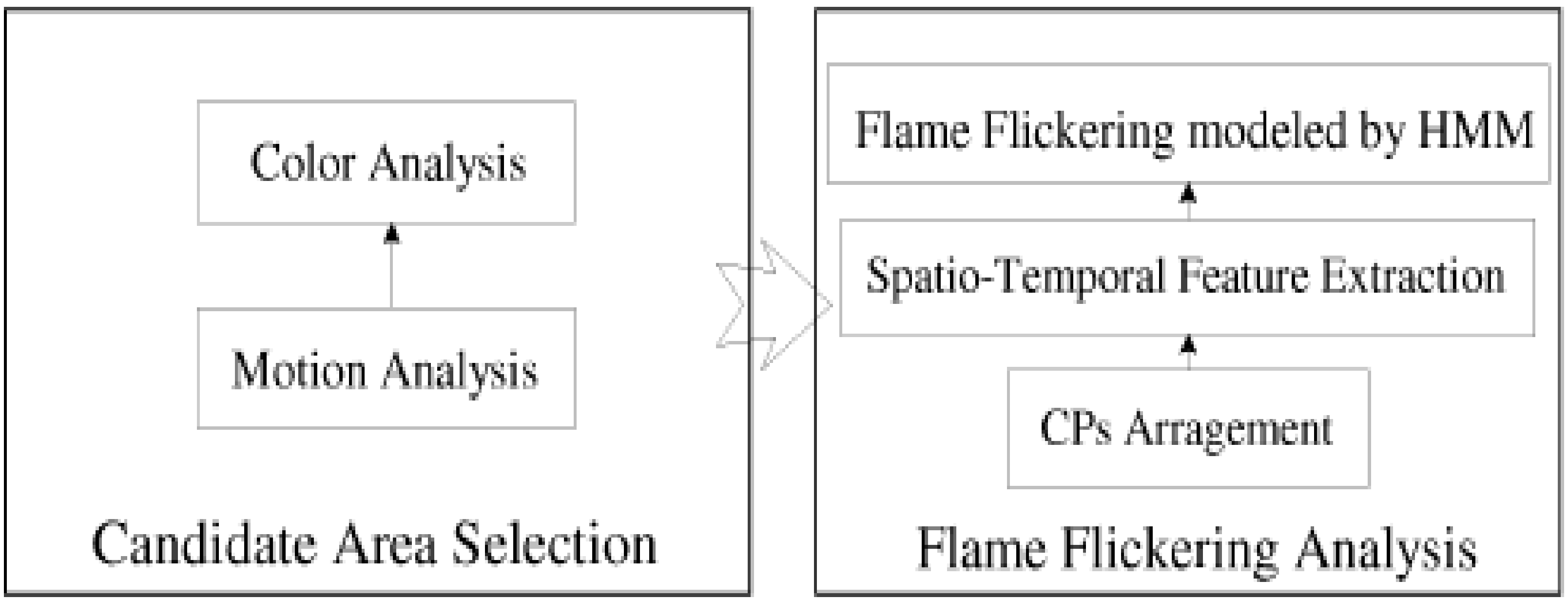
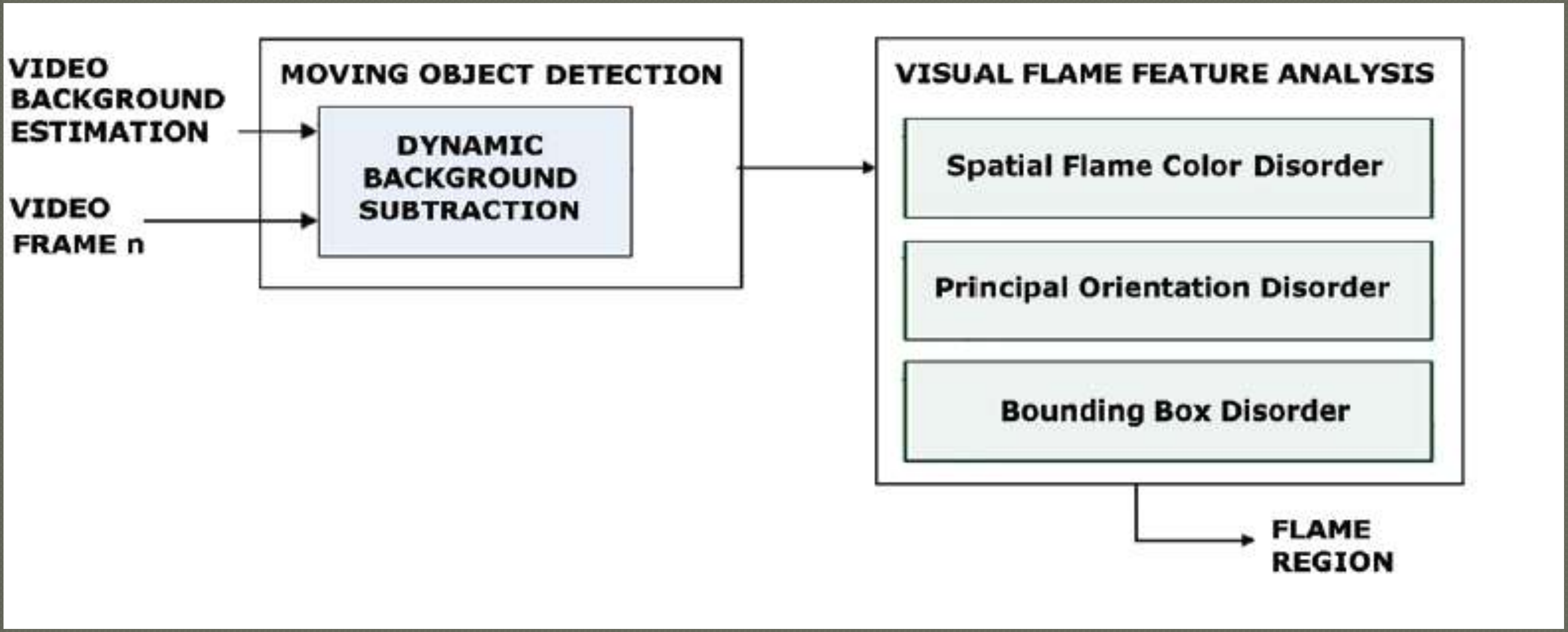


Fig. 2. The main process of our proposed fire detection algorithm.

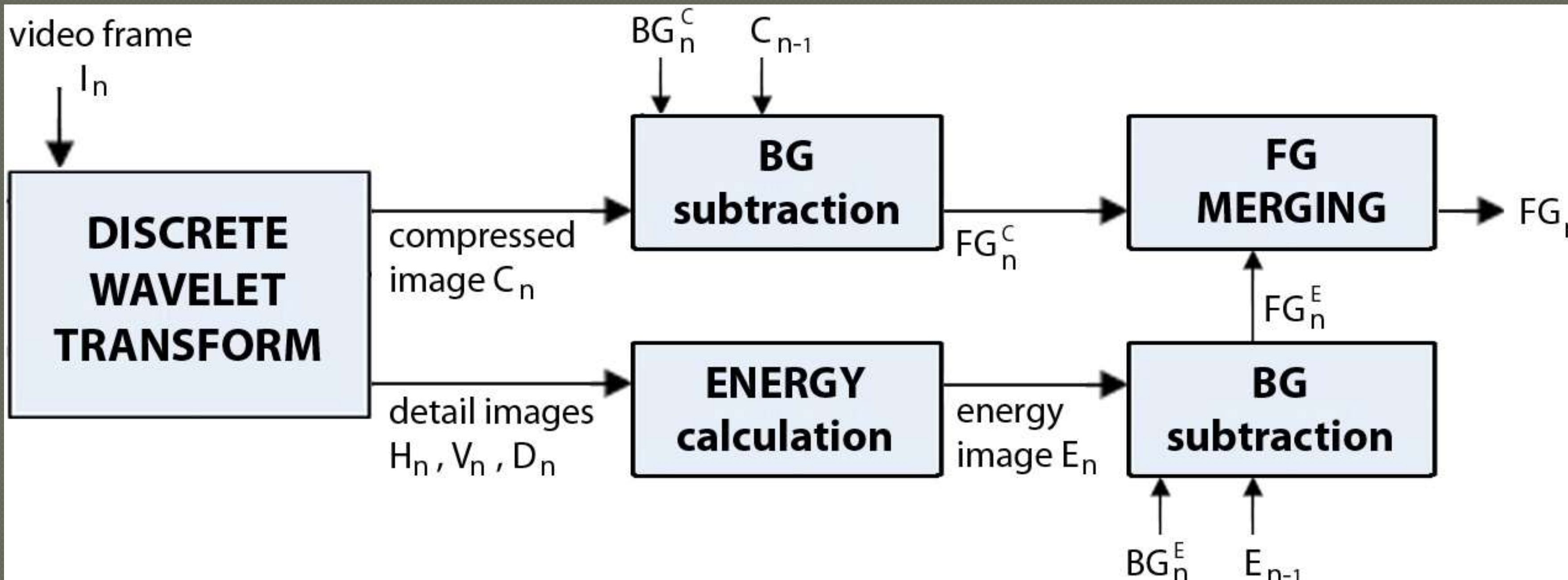
Advantages of Hidden Markov model

- Computational cost is low
- Provides Real time fire detection
- Low false alarm rate

Wavelet Based Multi-Modal Approach



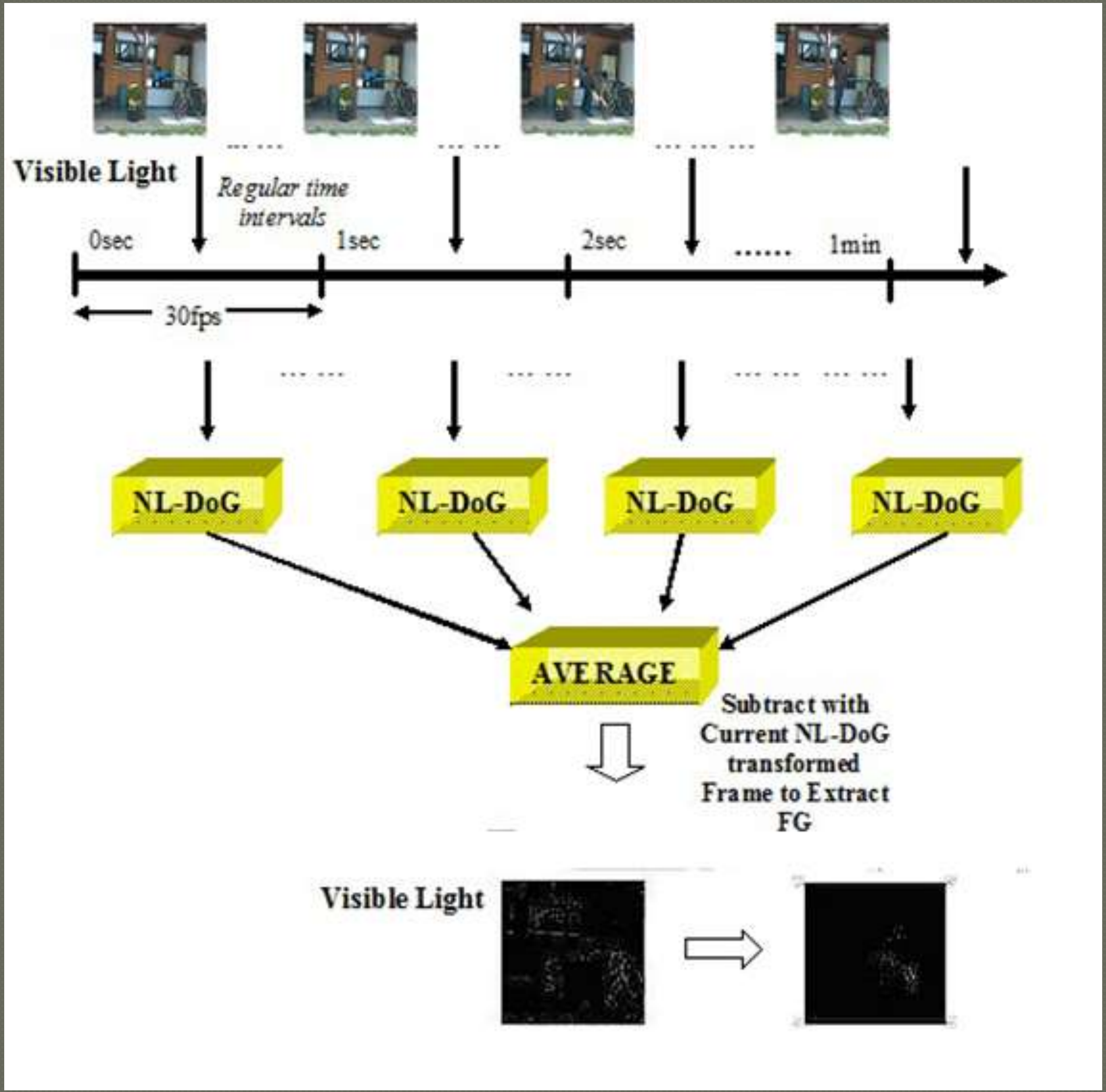
visual flame detector



DWT based FG extraction

$$BG_{n+1}[x,y] = \begin{cases} \alpha BG_n[x,y] + (1-\alpha)F_n[x,y] \\ \qquad\qquad\qquad\qquad \text{if } F_n[x,y] \to BG \\ BG_n[x,y] \\ \qquad\qquad\qquad\qquad \text{if } F_n[x,y] \to FG \end{cases} \tag{1}$$

$$E_n[x,y] = \sqrt{H_n^2[x,y] + V_n^2[x,y] + D_n^2[x,y]}$$


Visible Light
Regular time intervals
0sec
1sec
2sec
......
1min
30fps
NL-DoG
NL-DoG
NL-DoG
NL-DoG
AVERAGE
Subtract with Current NL-DoG transformed Frame to Extract FG
Visible Light

Advantages

- Reduces flame reflections
- False Alarms

Disadvantages

- Difficult to port as Real Time
- Human Interaction not considered
- No Verification algorithm
- Need of sufficient and specific conditions
- Variability of Shape , Motion , Colors and Patterns of fire and smoke

Hardware & Software Requirements

- Texas Instrument's Da Vinci Platform
  - C28x DSP core with floating point unit
  - ARM Cortex-M3 processor
- OpenCV library for testing
- Camera to provide real time feed (min. 12 fps)

Future Scope of the system

- Can be used in conjunction with existing surveillance systems.

- To be developed as a part of a larger surveillance system to be developed by Tata Elxsi Ltd.

Conclusion

• Initial promise with high success rates of up to 99% and only 0.3% failure rates.

• Cheaper alternative to the current sensor based devices.

• Can be integrated with current CCTV systems.

References

- http://en.wikipedia.org/wiki/Image_processing
- http://www.imageprocessingbasics.com/
- http://ieeexplore.ieee.org
- IEEE Papers referred :
  - Fire-Flame Detection based on Fuzzy Finite Automation
    SunJae Ham, ByoungChul Ko, JaeYeal Nam
  - A Novel Way for Fire Detection in The Video Using Hidden Markov Model
    Jian Ding and Mao Ye
  - Wavelet based multi-modal Fire Detection
    Steven Verstock, Ioannis Kypraios, Pieterjan De Potter, Chris Poppe, Rik Van de Walle
  - Fire Detection Based on hidden Markov Models
    Zhu Teng, Jeong-Hyun Kim,Dong-Joong Kang