# The detection of steam injection based on video surveillance

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## Abstract

In this paper, we focus on the visual features of steam injection and propose an integrated algorithm to detect it based on video surveillance. The proposed method is depended on three decision rules which are the attribute of gray level and the feature of frequent flicker rate of steam injection, and the similarity structure between background image and current frame. The block-based approach is applied to all three decision rules. The experimental results show that the algorithm provides a reliable detection method which is useful in many cases such as the alarm on the leakage of a heating pipe.

## Keywords

detection, steam, injection, based, video, surveillance

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# The detection of Steam Injection based on Video Surveillance

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*Abstract*—**In this paper, we focus on the visual features of steam injection and propose an integrated algorithm to detect it based on video surveillance. The proposed method is depended on three decision rules which are the attribute of gray level and the feature of frequent flicker rate of steam injection, and the similarity structure between background image and current frame. The block-based approach is applied to all three decision rules. The experimental results show that the algorithm provides a reliable detection method which is useful in many cases such as the alarm on the leakage of a heating pipe.**

*Keywords-steam injection detection; video surveillacne; structure similarity*

## I. INTRODUCTION

In this paper, we focus on the visual features of steam injection and propose an integrated algorithm to detect it based on video surveillance. The proposed method is depended on three decision rules which are the attribute of gray level and the feature of frequent flicker rate of steam injection, and the similarity structure between background image and current frame. The block-based approach is applied to all three decision rules. The experimental results show that the algorithm provides a reliable detection method which is useful in many cases such as the alarm on the leakage of a heating pipe.

## II. THEORY

There is little work done in the area of detecting the steam injection by video surveillance. Therefore, three visual features of the steam injection are mentioned in the following paragraphs to help us detect the target from complex background.

The first visual attribute of the steam injection is gray level. We get this thought from [1]-[4]. The color of the steam injection is white or milky-like similar to white smoke. In many cases, the gray level of the region with the steam injection is higher than the background image. Therefore, a lot of works which have been done on the subject of color feature of smoke merits our references and study on detecting vapor. In this paper, this feature will be used to be an initial criterion to accomplish our goal.

The second visual feature is the structure similarity of the image with steam injection, which is often used to assess image quality in previous analysis [5]-[6]. The steam injection will blur the scene of background image instead of blocking. In this paper, the structure similarity is applied as a tool to distinguish the blurredness from blocking. Thus, the structure similarity between current frame and background image is implemented as another effective decision rule in our algorithm.

The third visual character of our target is the flicker rate of the block image with steam injection, which is a novel parameter based on video surveillance. In [7], the flicker feature of the fringe of smoke is analyzed. The gray level of the pixels in the steam injection area change frequently and the frequency is much higher than other moving objects like smoke or a person. Thus, this feature, flicker rate of steam injection, plays a significant role on distinguishing the target from other substances. The implementation of this feature provides more reliable detecting results on the basis of above two decision rules.

## III. ALGORITHM

### A. Block dividing and color model

During the video surveillance, the data amount of processing and calculating is tremendous so that the target may not be detected promptly. It is time-consuming if we copper with all the data in one frame captured by the CCD (Charge-coupled Device) camera in the process of detecting the region with steam injection. In this paper, we use block dividing method to reduce the calculating time when the surveillance range is not small [7]-[8]. The frame captured by the camera is divided into some squares which is the fundamental unit processed in the whole detecting system. BL(nF,m,n) indicates each block in the No. nF frame while m and n are the coordinates. Moreover, another advantage of using block dividing method is that we could use the coordinates of the block to locate the region with steam injection precisely.

The color model used in this article is based on the gray level of each pixel which is calculated from the values of RGB (red, green, blue) components.

$$CF(nF,x,y,m,n) = \frac{1}{3}(R(nF,x,y,m,n) + G(nF,x,y,m,n)$$

$$+B(nF, x, y, m, n)) \qquad (1)$$

$$Bg(0, x, y, m, n) = \frac{1}{3}(R(0, x, y, m, n) + G(0, x, y, m, n)$$

$$+B(0, x, y, m, n)) \qquad (2)$$

Where nF indicates the number of current frame, (x,y) is the coordinates of a pixel in the block BL(nF,m,n). CF(nF,x,y,m,n) and Bg(0,x,y,m,n) are the gray levels of the pixel (x,y) in the No. nF frame and background image. R(nF,x,y,m,n), G(nF,x,y,m,n), R(nF,x,y,m,n) are the values of red, green and blue components of the pixel (x,y) in RGB color model. Instead of No. nF frame, R(0,x,y,m,n), G(0,x,y,m,n) and B(0,x,y,m,n) are the values of three color components of the pixel (x,y) in the background image. The gray level is used to extract ROIs (region of interests) which are changed during the surveillance time. In the following, we define whether a pixel is changed during the data processing.

$$CF(nF, x, y, m, n) - Bg(0, x, y, m, n) > TH\_Dif \qquad (3)$$

Where TH_Dif is the threshold. Whenever (3) is satisfied, the pixel (x,y) is defined to be changed on the No. nF frame. NoC(nF,m,n) is used to record the number of pixels satisfied the judging standards in the block BL(nF,m,n). In the first step of detecting, when NoC(nF,m,n) is greater than the threshold TH_NUM, this block is defined to be possible area with steam injection. The values of TH_Dif and TH_NUM both depend on the statistical data of experiments and the surveillance environments. For instance, in a room with the space 30 square meters, the range of the typical values of TH_Dif is from 20 to 40. In our experimental environments, the value is set to be 10. Meanwhile, the rate of TH_NUM to the number of pixels in one block, NUM, is from 1/5 to 1/3 with 1/4 in our experiments.

### B. The structure similarity

The pixels in natural images are highly structured with strong dependencies. Structural similarity is a measurement to structural information change. In order to achieve more accurate detecting results, another feature of steam injection referred to structure similarity is used as second criteria. Steam injection will blur the background image when they emit in front of the CCD camera. However, other moving objects like people will just change the background image instead of blurring it. Structure similarity between the background image and current frame is the metric to distinguish the blurring and alteration of the background image. In the following, we present the definition of the structure similarity adopted in this paper. Zhou Wang in [5] offers a novel thought about the image structure similarity. Instead of using luminance, we choose the gray level to define the structure similarity in our detecting system.

$$\mu(0, m, n) = \frac{\sum_x \sum_y Bg(0, x, y, m, n)}{NUM} \qquad (4)$$

$$\mu(nF, m, n) = \frac{\sum_x \sum_y CF(nF, x, y, m, n)}{NUM} \qquad (5)$$

$$\sigma(0, m, n) = \frac{1}{NUM} \sum_x \sum_y (Bg(0, x, y, m, n) - \mu(0, m, n))^2 \qquad (6)$$

$$\sigma(nF, m, n) = \frac{1}{NUM} \sum_x \sum_y (CF(0, x, y, m, n) - \mu(nF, m, n))^2 \qquad (7)$$

$$\sigma(0, nF, m, n) = \frac{1}{NUM} \sum_x \sum_y (Bg(0, x, y, m, n) - \mu(0, m, n))$$

$$\times (CF(0, x, y, m, n) - \mu(nF, m, n)) \qquad (8)$$

where $\mu(0,m,n)$ and $\sigma(0,m,n)$ represent the mean value and variance of gray level in the block BL(0,m,n) in the background image, $\mu(nF,m,n)$ and $\sigma(nF,m,n)$ represent the mean value and variance of gray level in the block BL(m,n) in the current frame (No. nF frame). $\sigma(0,nF,m,n)$ is the covariance between BL(0,m,n) and BL(nF,m,n). Other coefficients are the same as in section 3.1. Based on above equations from (4) to (9), the structural similarity ssim(nF,m,n) in block BL(nF,m,n) with the frame number nF is defined in (9):

$$ssim(nF, m, n) = \frac{2\mu(0, m, n)\mu(nF, m, n) + C_1}{\mu(0, m, n)^2 + \mu(nF, m, n)^2 + C_1}$$

$$\times \frac{2\sigma(0, nF, m, n) + C_2}{\sigma(0, m, n)^2 + \sigma(nF, m, n)^2 + C_2} \qquad (9)$$

where $C_1$ is a constant to avoid instability when $\mu(0,m,n)^2 + \mu(nF,m,n)^2$ is very near to zero. $C_2$ is another constant to avoid instability when $\sigma(0,m,n)^2 + \sigma(nF,m,n)^2$ is near to zero. In the following experiments, $C_1 = 6.5$ and $C_2 = 58.5$.

In following two groups of figures, we illustrate different variation trends of structure similarity in two blocks which are marked by black squares. In Fig. 1, we analyze the value of structure similarity in block BL(nF,10,9) from frame No.1 to frame No. 446. When steam injection emits, ssim(nF,10,9) fluctuates around 0.4. In Fig. 2, the variation curve of structure similarity in block BL(nF,4,5) is presented. When a moving object occurs in this block, the value of ssim(nF,,4,5) plunges from neatly 1 to -0.13. Through Fig. 1 and Fig. 2 we can find the differences of structural similarity between the region with steam injection and other objects. In our final experiments of detecting, we tend to consider there maybe steam injection in that region when the value of ssim(nF,m,n) is between 0.4 to 0.8.
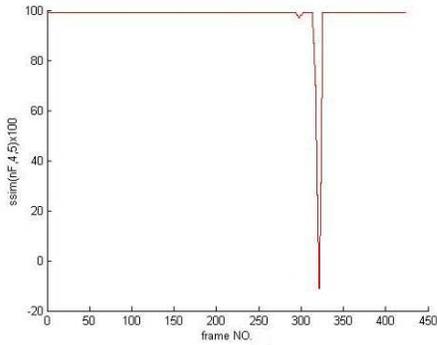


(a) One frame during video surveillanc
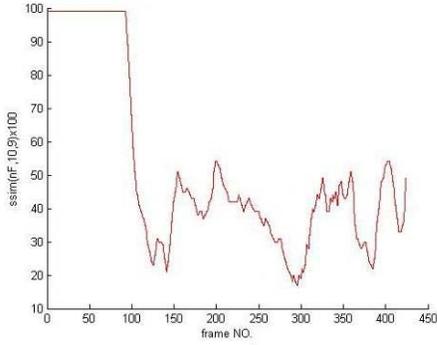
(b) Variation of ssim(nF,10,9) against frame number.

Figure 1.   The ssim(nF,10,9) in the block BL(nF,10,9) with steam injection



(a) One frame during video surveillance



(b) Variation of ssim(nF,4,5) against frame number

Figure 2.   The ssim(nF,4,5) in the block BL(nF,4,5) with a moving person

## C.  The frequent flicker feature of steam injection

Based on above two criteria, it is not enough to determine whether there is steam injection in the surveillance region. The little moving objects or little change of the background may influence the correctness of detection. Here, another feature of steam injection named flicker rate is applied in our detecting scheme to distinguish the target from others. In Fig. 3, a flow diagram details the whole progress of calculating flicker rate $fr(m,n)$ in block $BL(nF,m,n)$. We use $P(m,n)$ to denote the flag of block $BL(m,n)$ which is the indication whether the block satisfied above two criteria. If so, $P(m,n) = 1$; if not, $P(m,n) = 0$. Whenever a new frame captured by the CCD camera comes, we check each of the flags. If the two criteria are satisfied in the block $BL(nF,m,n)$ and $P(m,n) = 0$, then the value of $P(m,n)$


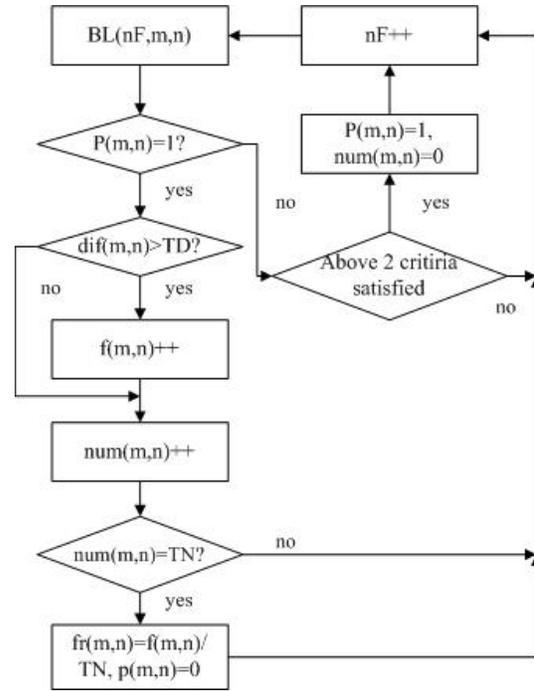
Figure 3.   The flow diagram of calculating the flicker rate in one block

will be changed into 1 and a new parameter $Num(m,n)$, the number of frames from the beginning of checking, is initialized to 0. In Fig. 3, $dif(m,n)$ is the number of changed pixels which are defined in 3.1 with threshold TD between two consecutive frames. Meanwhile, $f(m,n)$ records the number of flicker frames in one detecting cycle with period TA. After one cycle of TA frames, the flicker rate of one block is calculated.

In Fig. 4, differences of flicker rate between an area with steam injection and other moving objects are illustrated. The solid line (data1) represents the variations of flicker rate in the region with steam injection. The dashed line (data2) shows the trends of flicker rate in the area of a moving person. The abscissa axis represents the times of calculating the flicker rate. From Fig. 4, we conclude that the flicker rate of our target is much higher than other moving objects because normal moving objects like a person do not change the values of pixels as frequently as steam injection. Thus, the feature of flicker rate is implemented in our whole detecting system to enhance the reliability.
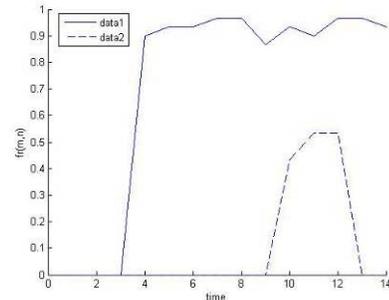


Figure 4.   The flicker rate of the area of steam injection (data1) and a moving person (data2)

## IV. EXPERIMENTS AND RESULTS

A series of theoretical analysis have been presented in the above sections, realistic experiments may provide more intuitive information to the whole algorithms. An ultrasonic humidifier is used to simulate the emitting of steam injection. A CCD camera with resolution 320*240 is put into use as the surveillance equipment. Three groups of experiments are illustrated in the following figures as examples. The left images in Fig. 5 are the background images with the final detecting results on the right. A red square is used to locate the area with steam injection. In group (a), there is only condensing vapor in the surveillance area. In group (b), there is no our detection target but a moving person. In group (c), there are both moving person and steam injection in the surveillance area. From these three groups of experiments, our target the steam injection is detected correctly with interfering factors such as a moving person.



(a)Only steam injection in the surveillance area



(b) Without steam injection in the surveillance area



(c)Both steam injection and moving person in the surveillance area

Figure 5.   Three groups of detecting results with different experimental conditions

## V. CONCLUSIONS

There are some peculiar visual features of steam injection which can be reflected by video surveillance and processing. Therefore, we develop a whole detecting algorithm and scheme, based on image processing, to find whether there is steam injection in the surveillance area. Three visual features of steam injection included gray level, structure similarity and flicker rate are fully explained and implemented in our detecting system to enhance the detection reliability. Experimental results show that our proposed algorithm provide a reliable method on detecting the target in the complex environments.

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