Using Fuzzy Inference System FIS for Identifying Motion in Digital Surveillance Systems

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Abstract. The aim of the current study is to use the FIS Fuzzy Inference System method to determine motion in digital surveillance systems. In the analysis, there are several methods used such as segmenting, sorting, evaluating and showing the results. After capturing an online video stream with an average of 1 frame/sec, the goal of the proposed method is to translate these frames to their corresponding representation of pixels and then use these frames as inputs for the job. The output is evaluated based on these inputs. The idea is to compare the average pixel representation of the current frame boundaries (column vectors) with the corresponding column vectors in the next frame, in order to find out whether there is any motion detected by comparing the average of the calculated column vector for the ith frame with the corresponding column vector in the i+1th frame. This operation leads to extracting 8 averages and it is considered as inputs to the fuzzy inference method. There is one output that will detect whether there is any motion detected or not. By designing a set of rules and then analyzing the results, a comparison of the averages is held.

Keywords. FIS, Digital surveillance systems, Fuzzy rules, Membership functions, Column vectors.

1. Introduction

Media technology and resources are important and essential area in the world to improve the quality of our daily experience [1]. An image is a visual representation of an object, a person, or a scene. A digital image is a two-dimensional function f(x, y) that is a projection of a 3-dimesionl scene into a 2-dimensional projection plane, where x, y represents the location of the picture element or pixel and contains the intensity value [2]. Video processing including still images and time varying images refers to pictorial (visual content), By all accounts, the segmentation and subsequent problems of video artifacts are separated but they are truly indivisible[3]. Generally, there are regularly sharp edge rich subtleties in plain video frames[4]. A image is a splitted into subframes of intensity that are constant with respect to time [5]. In using Fuzzy Logic, fuzzy inference method maps the input values given to one or more output values, where Fuzzy logic is an infinite value logic, with truth values in (0, 1)[6]. Fuzzy sets, membership functions (MFs) and relevant fuzzy rules have to be specified in order to do that. The data coming from the grid must be collected and processed in order to analyze and execute the entire FIS, [7]. In media like video or image, the term segmentation is considered an important technique. This segmentation process can be done by various methods, based on three categories; region based, intensity based and structure based, [8]. The paper is sectioned into an introduction about video processing, then the methodology of the proposed work,
which includes two steps: converting or splitting video to frames, processing these frames by using Fuzzy Inference System FIS, and the results for the experimented video, finally conclusions of the proposed work.

2. Video splitting process

In computer vision, video partitioning is the operation of splitting a video segment into multi frames (images). The goal of splitting is to simplify and/or change the description of a frame into something that is more meaningful and simpler to analyze [9]. Images taken by smartphones and modern cameras are typically comprised of millions of tiny squares called pixels. Each pixel in a digital image takes on some color or shade of color. [10]. In order to blur/deblur, we must have a model that relates the given blurred frame to the unknown true frame, [11].

3. Methodology

In this paper a model is designed for identifying any motion in digital surveillance systems by combining fuzzy rules set with an online grayscale video streaming analysis. Video processing systems and computer vision require high to moderate resolution data in a timely manner to extract useful information, which could mean anything [12]. The work is partitioned into two major steps; first is video processing and second is constructing Fuzzy Inference System FIS. The system will be useful for security in a fixed restriction area [13]. For the first step, a video stream is split into a sequence of frames(images). Each frame is a matrix of pixels. Practically, a video stream used for five seconds and five frames are obtained by average of 1 frame/sec. For simplicity, it is considered that the image(frame) is consisting of 6*6 dimension. The proposed method is that, first the pixels representation is obtained for each frame as explained in figure 1:

![Figure 1](image.png)

Figure 1. Digital image representation by pixels for 6*6 sample frame.

Second, the edges of the determined frame are extracted and converted into four column vectors as explained in figure 2:

![Figure 2](image.png)

Figure 2. Extracting the boundaries of the frame in figure 1.
The first and second frames are taken and then the four column vectors of both frames are extracted. After applying the comparison using the FIS system, the average of the pixels' intensities for each of the derived column vectors for the current frame is calculated and this operation is repeated for the next frame by extracting also the edges of the frame that represent four column vectors. The next step is finding the average for each. This operation is executed through the following equations:

\[
\alpha_{(x,k)} = \frac{\left( \sum_{i=0}^{m} \Psi[x,k](0,i) \right)}{m} \\
\alpha(x+1,k) = \frac{\left( \sum_{i=0}^{m} \Psi[x+1,k](0,i) \right)}{m} \\
\alpha(x,k+1) = \frac{\left( \sum_{j=0}^{n-1} \Psi[x,k+1](j,0) \right)}{n} \\
\alpha(x+1,k+1) = \frac{\left( \sum_{j=0}^{n-1} \Psi[x+1,k+1](j,0) \right)}{n} \\
\alpha(x,k+2) = \frac{\left( \sum_{i=0}^{m} \Psi[x,k+2](n-1,i) \right)}{m} \\
\alpha(x+1,k+2) = \frac{\left( \sum_{i=0}^{m} \Psi[x+1,k+2](n-1,i) \right)}{m} \\
\alpha(x,k+3) = \frac{\left( \sum_{j=0}^{n-1} \Psi[x,k+3](j,m-1) \right)}{n} \\
\alpha(x+1,k+3) = \frac{\left( \sum_{j=0}^{n-1} \Psi[x+1,k+3](j,m-1) \right)}{n}
\]

Through the equations above, the comparison between the current and the next frame can be derived. Where: \( \alpha \) : the average of the determined column vector, \( x \) : frame number, \( m \) : the total no. of columns in the frame, \( n \) : the total no. of rows in the frame and \( k \) : column vector number for the determined frame.

Figure 3, it is noticed that the general structure is finding the comparisons between the average of the \( i^{th} \) column vector in the current frame with the corresponding column vector in the next frame. After extracting these comparisons, we used them in the proposed fuzzy inference system FIS class of objects with a continuum of grades of membership. Such a set is characterized by a membership [14]. The main concepts in fuzzy logic are: linguistic variables, linguistic modifiers propositional fuzzy logic, deductive inference rules, and approximations [15]. Depending on the structure of the fuzzy set, the system structure is determined, [16]. The determined structure for the fuzzy inference system FIS consists of eight inputs that represent the averages calculated above for the \( i^{th} \) frame and \( i^{th}+1 \) frame with five membership functions for each input and one output with two membership functions. After that the general rules set is constructed which determines if there is no motion detected in the video stream, or there is any motion detected. This operation is executed by comparing the average of the pixels intensities of the the first column vector for the first frame with the average of the corresponding one in the second frame. Then the average of the second column vector for the first frame is compared with the average of corresponding one in the second frame, and so on. Then it is determined whether there is any motion resulting between these two frames depending on the proposed rules set. If there is no motion detected between the first and the second frame, in this case, the second frame boundaries are compared with the third frame with deletion of the data of the first frame and so on.
Figure 3. The comparisons between the averages of the current and the next frame.

4. Proposed fuzzy inference system

The estimation of membership functions from data is an important step in many applications of fuzzy theory [16]. A proposed membership functions is constructed for both inputs and outputs for the proposed fuzzy rules set, displayed in Table 1. The membership functions for the determined inputs are (Dark, Low_gray, Mid_gray, High_gray and White) and the membership functions for the output are (No_diff, Diff_detect) as explained figure 4:

After applying the proposed FIS rules on the determined inputs, the result is compared to the membership functions of output. If the result is within the range of membership function (No_diff), which means that there is no motion detected between the determined frames, else there is a motion detected.

The outline structure for the proposed work display the two work steps, video processing and fuzzy inference system (Fuzzification, Membership functions constructing and defuzzification), as displayed in figure 5.

| Table 1. The structure of the proposed fuzzy rules. |
|-----------------------------------------------|
| Rule No. | Fuzzy rules                                      |
|---------|-------------------------------------------------|
| 1.      | If $a(x,k)$ & $a(x+1,k)$ are dark or If $a(x,k)$ & $a(x+1,k)$ are low_gray or If $a(x,k)$ & $a(x+1,k)$ are mid_gray or If $a(x,k)$ & $a(x+1,k)$ are high_gray or If $a(x,k)$ & $a(x+1,k)$ are white Then Output is no_motion |
| 2.      | If $a(x,k+1)$ & $a(x+1,k+1)$ are dark or If $a(x,k+1)$ & $a(x+1,k+1)$ are low_gray or If $a(x,k+1)$ & $a(x+1,k+1)$ are mid_gray or If $a(x,k+1)$ & $a(x+1,k+1)$ are high_gray or If $a(x,k+1)$ & $a(x+1,k+1)$ are white Then Output is no_motion |
| 3.      | If $a(x,k+2)$ & $a(x+1,k+2)$ are dark or If $a(x,k+2)$ & $a(x+1,k+2)$ are low_gray or If $a(x,k+2)$ & $a(x+1,k+2)$ are mid_gray or If $a(x,k+2)$ & $a(x+1,k+2)$ are high_gray or If $a(x,k+2)$ & $a(x+1,k+2)$ are white Then Output is no_motion |
| 4.      | If $a(x,k+3)$ & $a(x+1,k+3)$ are dark or If $a(x,k+3)$ & $a(x+1,k+3)$ are low_gray or If $a(x,k+3)$ & $a(x+1,k+3)$ are mid_gray or If $a(x,k+3)$ & $a(x+1,k+3)$ are high_gray or If $a(x,k+3)$ & $a(x+1,k+3)$ are white Then Output is no_motion |
| 5.      | Else Output is motion_detect                      |
Figure 4. (Left) The membership functions for the determined output, (Right) The membership functions for the determined inputs.

Figure 5. Outline for the proposed work analysis.
5. Experiment results and discussions

The experiment is simulated using Matlab and the results of the experimented video segment are shown in table 2 and 3.

**Table 2.** The average of every column vector for each extracted frame.

| 1 frame/sec. | Avg. of column vector1 | Avg. of column vector2 | Avg. of column vector3 | Avg. of column vector4 |
|--------------|-------------------------|------------------------|------------------------|------------------------|
| Frame0       | 135                     | 169                    | 201                    | 177                    |
| Frame1       | 135                     | 170                    | 200                    | 182                    |
| Frame2       | 140                     | 166                    | 200                    | 176                    |
| Frame3       | 133                     | 166                    | 201                    | 175                    |
| Frame4       | 30                      | 55                     | 207                    | 165                    |

Mathematically, form the experimented data for the determined five frames in table1, there is a motion detected between frames 3 and 4 in column vectors 1 and 2 through the differences between the \(i^{th}\) column vector in the current frame and corresponding one in the next frame as displayed in table2.

**Table 3.** The quantitative values of output in the proposed FIS.

| Coloum vector no. | Diff (frame0, frame1) | Diff (frame1,frame2) | Diff (frame2,frame3) | Diff (frame3,frame4) |
|-------------------|-----------------------|----------------------|----------------------|----------------------|
| 1                 | 0                     | 5                    | 6                    | 103                  |
| 2                 | 1                     | 4                    | 0                    | 111                  |
| 3                 | 1                     | 0                    | 1                    | 6                    |
| 4                 | 5                     | 6                    | 1                    | 10                   |

Depending on the derived analyzed data displayed in table1, we found the comparision between the column vectors of the \(i^{th}\) frame with the corresponding column vectors in \(i^{th}+1\) frame. Depending on the experimented frames from table2, the initial data set was the pixels’ intensities for each column vector in the first frame and the pixels’ intensities for each column vector in the second frame. Now the equations above (1-8) can be applied and eight average values are obtained. So, from Table 2 it is noticed that in the first three frames, there is no big difference between the column vectors in a determined frame and the corresponding column vectors in the next frame. This means that there is no motion detected between these frames, while between the 4\(^{th}\) and 5\(^{th}\) frames, there is a change or a big difference between frames 3 and 4 in the column vectors 1 and 2 for both frames. This difference is displayed in table3. Now after getting the averages in the previous step, we moved to the next step, these derived values for the first and the second frames were applied to the fuzzy inference system in order to determine whether there is any motion detected between these two frames. From the rules above, it is noticed that with each rule the average of each boundary was compared with the corresponding one in the next frame. Depending on the results it be can determine whether an motion is there-or between the determined frames.

6. Conclusions

The aim of the research is to use the FIS Fuzzy Inference System method to determine motion in digital surveillance systems through analyzing online gray scale video stream frame by frame to find whether there is any motion detected by designing a proposed algorithm to deal with this case. For simplicity, a five-second video stream was selected and five frames wee extracted by 1 frame/sec. After applying video processing and extracting of the four-column vectors (boundaries) for the ith frame and ith+1 frame, the average for first column vector for the ith frame was compared with the corresponding one in the ith+1 frame. The comparison was processed by using a proposed FIS. From table 1, it is noticed that the comparison between column vector 1 in frame 3 and column vector 1 in frame 4 is equal to the value 103. Also in the same frames but in column vector 2 for both, the difference was equal to 111. When applying these values to the output membership functions, it was noticed that it is located in the range of (Diff_detct) membership function, and that means there is a
motion detected between these two frames, while other frames comparisons where located in the range of (No_diff) membership function. This means that there is no motion detected between these frames. For the future development of the work, the development can be applied in many video processing fields using FIS, like moved object detection, face detection, etc..

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