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A Seat Position Labeling Algorithm Based on Improved Edge Operator and Gray Projection

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Abstract. *Aiming at the problem of attendance statistics with the methods of seat calibration through video monitoring in cinema, a seat position labeling algorithm based on improved edge operator and gray projection is presented. This method uses the improved Canny operator to detect the seat edge: Firstly, remove the noise through bilateral filtering, while keeping the edge of the image, then use Sobel operator to extract the primary horizontal and vertical edges respectively, at last, after dealing with the non-maximum suppression and double threshold, we get whole horizontal and vertical edges of the image. We project the horizontal edge of the image horizontally and isolate the best optimal horizontal partition position from the projection sequence, then calculate the vertical projection of the vertical edge for each row of seats and isolate the best optimal seat partition position for each row of seats. Finally, we realize the automatic labeling of all the seats in the auditorium.*
Keywords: Canny operator, Edge extraction, Gray-level projection, Seat position labeling.

1. **Introduction.** With the development of the film industry, the number of cinema rose, and it also increases the difficulty for the effective supervision of the theater. Some theaters, in order to obtain higher economic benefits, have made the film's box office data to be false, so that they can illegally obtain more box office revenue and reduce the division of creative team and management departments. This behavior damages the healthy development of the movie industry [1].
As the important research topic of intelligent monitoring, Intelligent Monitoring provides state-of-the-art alarm monitoring software for security control rooms. Intelligent Monitoring software is in wide spread use by Commercial, Corporate and Government to monitor burglar, fire and guarding systems in homes alarms, industrial alarms, resort security, government department security, mining house security, chain store security and businesses security systems. Intelligent Monitoring software is the multiple users'

Windows-based networkable automation software. All Intelligent Monitoring alarm monitoring and automation software for the modern day security control room is backed-up by a Dealership network with 24 hours telephonic support. The real-time surveillance video could be gotten and the status in the cinema could be accurately grasped through the video monitoring system in cinema screens. By means of computer vision, the video could be calibrated and analyzed, and then we can accurately obtain the information of theater attendance and provide the objective judgment for the box office.

The prerequisite for the statistics of attendance by means of computer vision is that the seat area is well calibrated. In general, a movie theater has dozens to hundreds of seats. Manual calibration is a waste of time and effort. As the theater seat style is not uniform, it's unable to adopt the method of machine learning. A seat labeling algorithm based on improved edge operator and gray projection is presented here.

2. **Method.** The practical application system is shown in Figure 1. The system includes edge extraction, Horizontal segmentation, Vertical segmentation, and fusion segmentation. Firstly, remove the noise through bilateral filtering, while keeping the edge of the image, then use Sobel operator to extract the primary horizontal and vertical edges respectively, at last, after dealing with the non-maximum suppression and double threshold, we get whole horizontal and vertical edges of the image. We project the horizontal edge of the image horizontally and isolate the best optimal horizontal partition position from the projection sequence, then calculate the vertical projection of the vertical edge for each row of seats and isolate the best optimal seat partition position for each row of seats. Finally, we realize the automatic labeling of all the seats in the auditorium.

2.1. **Edge extraction.** Due to the different material and color of the seat, the gray level of the image is not the same , so we cannot use the gray information of the image directly. In this condition, we use the edge extraction algorithm to calculate the edge information, so that different halls can complete unification. We use the improved Canny operator to extract the edge.

A. Traditional canny operator. Canny thinks that a good edge extraction operator should have the following 3 characteristics [2]: Good signal to noise ratio, high positioning accuracy, and single edge response.

According to the above three principles, Canny has derived an approximation of the optimal edge detection operator, that is, the boundary points are located in the maximum value of the gradient magnitude which is smoothed by Gauss function. The implementation of the scheme is presented as follows [3]:

- **Step 1** To reduce the impact of noise, smooth the image with 2D Gauss filter $G(i,j)$. The smoothed image is

$$H(i,j) = G(i,j) * I(i,j) \tag{1}$$

where $I(i,j)$ represents the original image and $H(i,j)$ represents the filtered image.

- **Step 2** Use the finite difference calculation of the first order partial derivative to calculate and preserve the horizontal direction derivative G_x and the vertical direction derivative G_y. Then use the directional derivatives to calculate the gradient amplitude and gradient direction θ.

$$M(i,j) = \nabla I(i,j) = \sqrt{{G_x}^2(i,j) + {G_y}^2(i,j)}; \theta(i,j) = \tan^{-1}\left({G_y}^2(i,j)/{G_x}^2(i,j)\right) \tag{2}$$

- **Step 3** In order to locate the edge point, non-maximum suppression (NMS) is carried out for the gradient value of each pixel. In the 3×3 neighborhood of the current pixel, if the gradient magnitude of the current pixel is greater than that of two adjacent

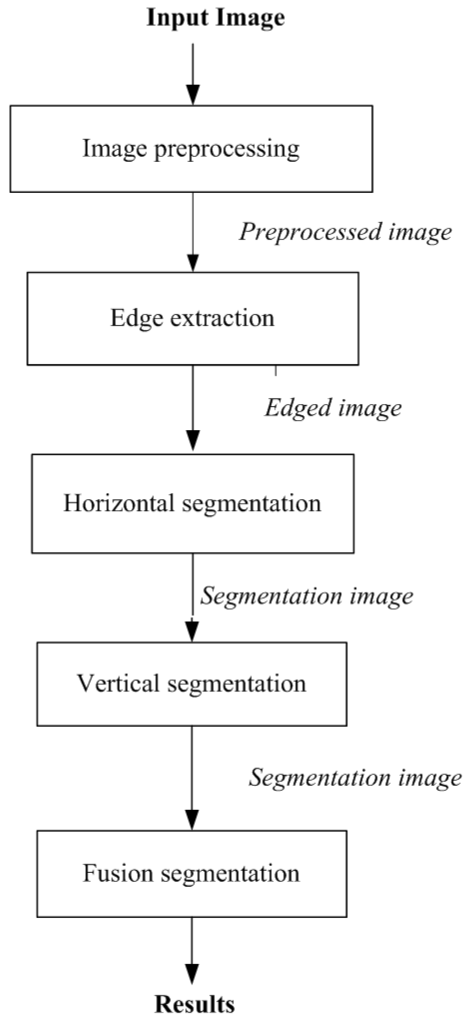

FIGURE 1. Framework of the practical application

pixels along the gradient direction, this point is considered to be the possible edge point and its corresponding flag is set to 1. Otherwise, the point is not an edge point and its corresponding flag is set to 0.

- **Step 4** After suppressed by non-maximum value, the image is processed by double threshold to eliminate the false edge and connect the intermittent edge, that is, calculate the high threshold by the given coefficient and image histogram. Then the low threshold is calculated by a given low threshold coefficient. After that, compare the high threshold with the non-maximum suppression image and the edge points are recorded. For all the edge points marked, look for points greater than low threshold by iteration in the 8 neighborhood and mark them as edge points. After process, we can get the edge image with the single edge width.

B. Improved Canny algorithm. In the traditional Canny operator , it takes 2D Gaussian filter to smooth the image and remove the noise, but Gaussian filter also makes image edge blur and appear the edge positioning and omission, so we select the bilateral filtering algorithm with the edge preserving and denoising function. Bilateral Filtering is an image filtering technique proposed by Tomasi and Manduchi. A bilateral filter is a non-linear, edge-preserving and noise-reducing smoothing filter for images. The intensity value at each pixel in an image is replaced by a weighted average of intensity values from nearby pixels. This weight can be based on a Gaussian distribution. Crucially, the weights depend not only on Euclidean distance of pixels, but also on the radiometric differences (e.g. range differences, such as color intensity, depth distance, etc.). This preserves sharp edges by systematically looping through each pixel and adjusting weights to the adjacent pixels accordingly. It is based on a two-scale decomposition of the image into a base layer, encoding large-scale variations, and a detail layer. Only the base layer has its contrast reduced, thereby preserving detail. The base layer is obtained using an edge-preserving filter called the bilateral filter. This is a non-linear filter, where the weight of each pixel is computed using a Gaussian in the spatial domain multiplied by an influence function in the intensity domain that decreases the weight of pixels with large intensity differences.

The image filtering techniques mostly take convolution of image data by design a two dimensional filter, and also get an image tended to expected result. Its a typical application to remove the noise from an image by image filtering method. The traditional image filtering supposed that the gray level of the pixel in an image is similar to that of the pixel in the neighborhood, but uncorrelated with the noise. So, the image filtering removes noise by low pass filter. Consider that the pixels on the edge have a large difference with the both sides. It cannot avoid filter out the high frequency component of the edge pixels, resulting in the loss of edge information. For image f (q), take low pass filter in space, then get image h (q). The low pass filter of image can be described as follow:

$$\mathrm{h}\left(\mathrm{q}\right)=\mathrm{k}_{\mathrm{d}}^{-1}\left(\mathrm{q}\right)\int\limits_{-\infty}^{+\infty}\int\limits_{-\infty}^{+\infty}\mathrm{f}\left(\epsilon\right)\mathrm{c}\left(\epsilon,\mathrm{q}\right)\mathrm{d}\epsilon \tag{3}$$

$\mathrm{c}\left(\epsilon,\mathrm{q}\right)$ is the spatia l proximity relation between the center pixel with the neighbor pixel, and can be expressed by Gauss function:

$$\mathrm{c}\left(\epsilon,\mathrm{q}\right)=\exp\left(-\frac{\left(\epsilon-\mathrm{q}\right)^{2}}{2\sigma_{\mathrm{d}}^{2}}\right) \tag{4}$$

The normalized function of $\mathrm{c}\left(\epsilon,\mathrm{q}\right)$

$$\mathrm{k}_{\mathrm{d}}\left(\mathrm{q}\right)=\int\limits_{-\infty}^{+\infty}\int\limits_{-\infty}^{+\infty}\mathrm{c}\left(\epsilon,\mathrm{q}\right)\mathrm{d}\epsilon \tag{5}$$

Space position and intensity similarity are combined nonlinearly by Bilateral Filtering to deal with the intensity and color information of pixels. The intensity of each pixel in image is replaced by the mean value of its neighborhood to be filtered. Bilateral Filtering of image can be expressed as:

$$\mathrm{h}\left(\mathrm{q}\right)=\mathrm{k}_{\mathrm{r}}^{-1}\left(\mathrm{q}\right)\int\limits_{-\infty}^{+\infty}\int\limits_{-\infty}^{+\infty}\mathrm{f}\left(\epsilon\right)\mathrm{c}\left(\epsilon,\mathrm{q}\right)\mathrm{s}\left(\mathrm{f}\left(\epsilon\right),\mathrm{f}\left(\mathrm{q}\right)\right)\mathrm{d}\epsilon \tag{6}$$

where $\mathrm{c}\left(\epsilon,\mathrm{q}\right)$ denotes the relation between the central pixel and its neighborhood. Besides, $s(f(\epsilon),f(q))$ denotes the image similarity which can be defined as

$$\mathrm{s}\left(\mathrm{f}\left(\epsilon\right),\mathrm{f}\left(\mathrm{q}\right)\right)=\exp\left(-\frac{\left(\mathrm{f}\left(\epsilon\right)-\mathrm{f}\left(\mathrm{q}\right)\right)^{2}}{2\sigma_{\mathrm{r}}^{2}}\right) \tag{7}$$

The normalized function of Bilateral Filtering $k_r(q)$ is defined as

$$\mathrm{k_r}(\mathrm{q}) = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} \mathrm{c}(\epsilon, \mathrm{q})\, \mathrm{s}(\mathrm{f}(\epsilon), \mathrm{f}(\mathrm{q}))\, \mathrm{d}\epsilon \tag{8}$$

For a smooth area in image, the intensity of pixels is constant, and Bilateral Filter degenerates to normal low-pass filter. While in the fluctuating area, the impact of dissimilar pixels declines sharply, only intensity similar to edge is useful. Mean intensity of similar pixels in the neighborhood is used to replace that of original intensity which means that the edge is dealt with specially. Thus image details with high frequency are kept after Bilateral Filtering and the results are shown in Figure 2 and Figure 3.

Figure 2. Original image with noise

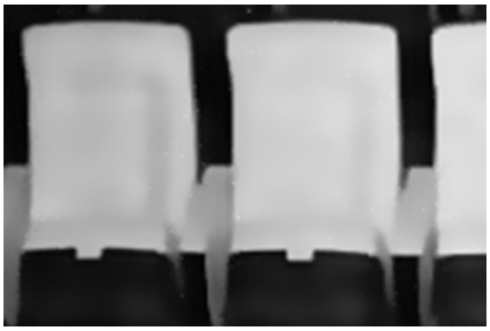

Figure 3. Image after Bilateral Filtering

We can see that noise is removed from original image after Bilateral Filtering and the edges are kept.

C. Orientation Departure. It is obvious that edges of seats focus on the horizontal and vertical orientations and there are few efficient edges of other orientations. Thus we improve original canny operator to extract horizontal and vertical edges exactly. To extract horizontal edges, gradient operator is replaced by first order Sobel operator [6] which is defined as

$$\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \tag{9}$$

The rest steps keep unchanged and the horizontal edges I_h^{edge} detected are shown as follows.

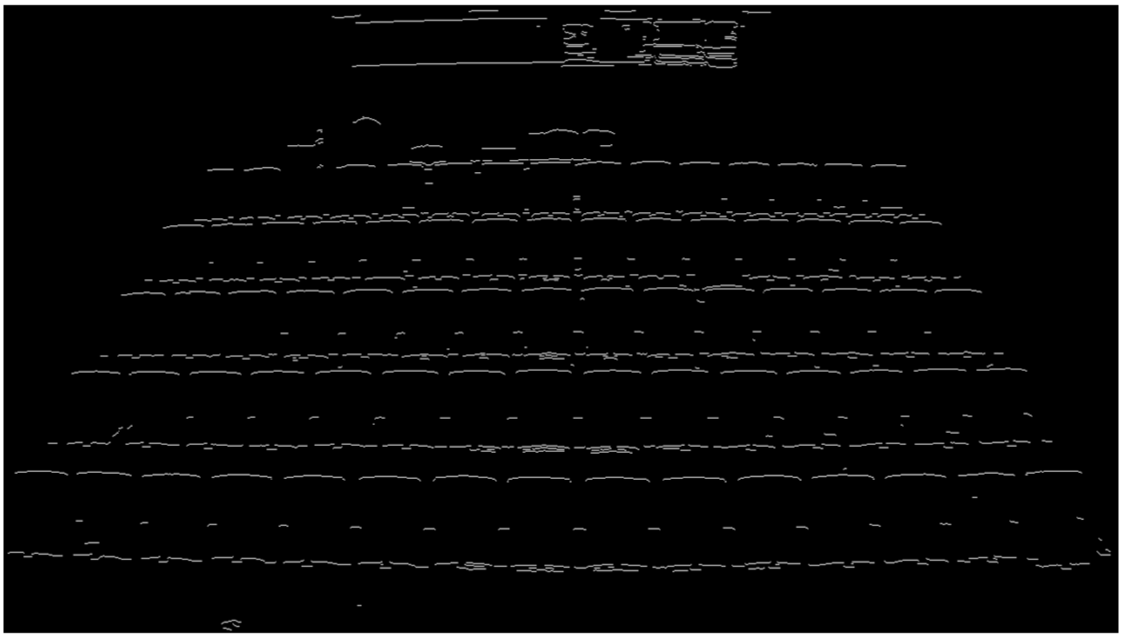

FIGURE 4. Detection of horizontal edges with canny operator

As shown in Figure 4, it is obvious that horizontal edges are extracted exactly by the improved method which is good for subsequent project computation. In similar manner, the vertical edges are extracted by Sobel operator which is defined as

$$\begin{bmatrix} -1 & 0 & -1 \\ -2 & 0 & -2 \\ -1 & 0 & -1 \end{bmatrix} \tag{10}$$

The vertical edges I_v^{edge} detected are shown in Figure 5.

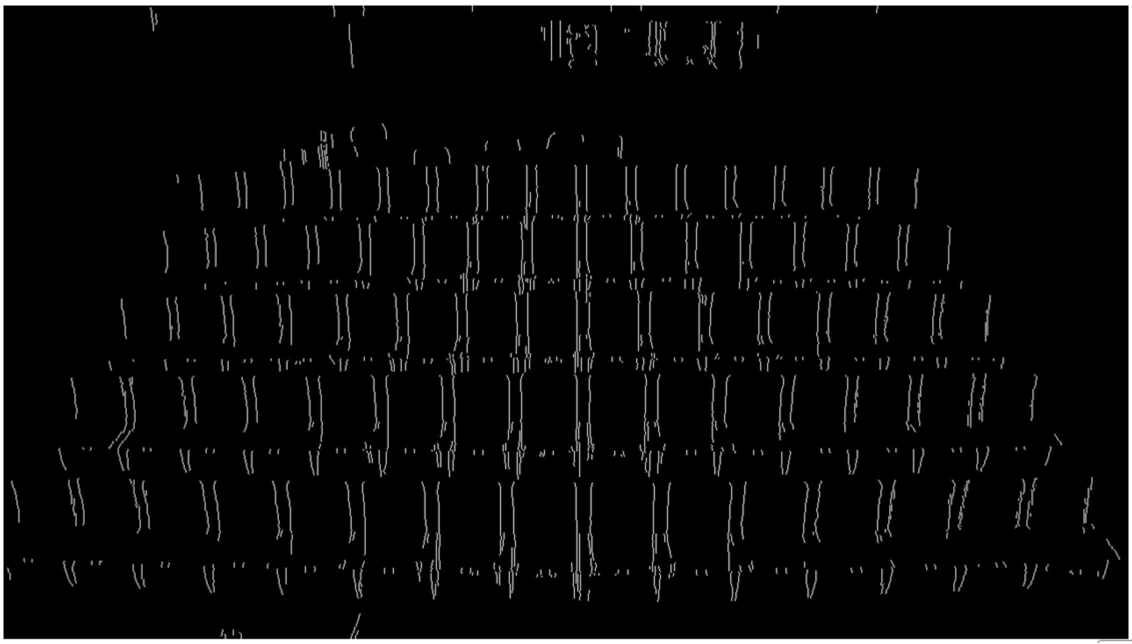

FIGURE 5. Detection of vertical edges with canny operator

In fact, some edges around the seats may be included to affect subsequent segmentation. Thus a mask is manually set to remove disturbance which is shown in Figure 6.

FIGURE 6. Mask of seat area

2.2. **Horizontal segmentation.** It is obvious that the seats are distributed regularly in the image. Each row of seats is segmented before each seat is segmented. Image is processed with horizontal projection

$$\mathrm{S_h}(\mathrm{i}) = \sum_{\mathrm{j}=0}^{\mathrm{N}} \mathrm{I_h^{edge}}(\mathrm{i},\mathrm{j}) \tag{11}$$

where S_h denotes the sequence of horizontal projection and $I_h^{edge}(i,j)$ denotes the intensity value at i row and j column of edge image with width N. Filtering is performed by mean value on intensity projection sequence to remove disturbance.

$$\mathrm{S_h^s}(\mathrm{i}) = \begin{cases} \frac{1}{2\mathrm{w}} \sum\limits_{\mathrm{k}=-\mathrm{w}}^{\mathrm{w}} \mathrm{S_h}(\mathrm{i}+\mathrm{k}) & \mathrm{w} \le \mathrm{i} < N - w \\ \mathrm{S_h}(\mathrm{i}) & (\, i < w) \cup (i \ge N - w) \end{cases} \tag{12}$$

The result is shown in Figure 7.

At first, position is obtained of each peak point. We compute the first order and second order derivative of filtered signal. The peak position is located where its value is bigger than the mean value, the first order is zero and the second order is negative.

$$\mathrm{S_{peak}}(\mathrm{k}) = \mathrm{i} \quad \text{if}\,(\mathrm{S_h^s}(\mathrm{i}) > \mathrm{S_h^{avg}}) \;\cap \left(\dot{\mathrm{S}}_\mathrm{h}^\mathrm{s}(\mathrm{i}) == 0\right) \cap \left(\ddot{\mathrm{S}}_\mathrm{h}^\mathrm{s}(\mathrm{i}) < 0\right) \tag{13}$$

There are many peaks in the projection image which denote the edges of seat back, surface and handrail. Our goal is only to get the count of upper edge of seats and peaks denoting other edges should be removed. In fact, edges of back and surface are close and there are two adjacent edges on the edge of the seat back to the upper edge of the next. The above can be used to remove the unnecessary peak points. After get the mean

FIGURE 7. Projection of horizontal edges

distance D_{avg} among adjacent peak points $S_{peak}(i)$, those are marked whose distance is smaller than the mean distance. Only those with larger value are kept which denote the edges of seats back.

$$\mathrm{S^{c}_{peak}}\left(\mathrm{k}\right) = \max\left(\mathrm{S_{peak}}\left(\mathrm{i}\right),\ \mathrm{S_{peak}}\left(\mathrm{i}+1\right)\right)\ if\left(\left|\mathrm{S_{peak}}\left(\mathrm{i}\right) - \mathrm{S_{peak}}\left(\mathrm{i}+1\right)\right| < \mathrm{D_{avg}}\right) \tag{14}$$

2.3. **Vertical segmentation.** Due to similarity of each row, it is also similar to extract one seat from each row , here we select a row randomly.

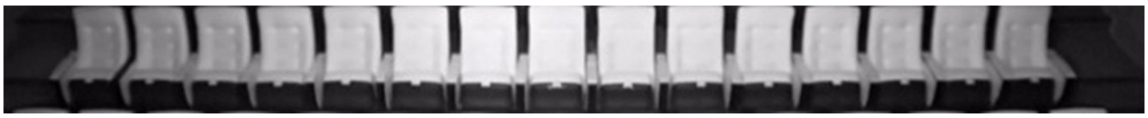

FIGURE 8. Image of a row of seats

For the example in Figure 8, the result shown in figure 9, the edges of seats on the upper part of the image are neat, so we do vertical gray-level projection operation only on the upper part of the image.

$$\mathrm{S_v}\left(\mathrm{j}\right) = \sum_{\mathrm{i}=0}^{\mathrm{Mc}/2} \mathrm{I_v^{edge}}\left(\mathrm{i},\mathrm{j}\right) \tag{15}$$

where S_v is the vertical projection sequence$I_v^{edge}(i,j)$ is the value of edge image on the i^{th} row, j^{th} column and Mc is the height of the clipped image.

Then we use median filter (see eq. 16) to remove the burr and get the following one-dimensional sequence (see Figure 10).

$$\mathrm{S_v^s}\left(\mathrm{j}\right) = \begin{cases} \frac{1}{2\mathrm{w}} \sum\limits_{\mathrm{k}=-\mathrm{w}}^{\mathrm{w}} \mathrm{S_v}\left(\mathrm{j}+\mathrm{k}\right) & \mathrm{w} \leq \mathrm{j} < Mc - w \\ \mathrm{S_v}\left(\mathrm{j}\right)\ \left(\ j < w\right) \cup \left(j \geq Mc - w\right) & \end{cases} \tag{16}$$

Figure 9. Vertical edges of seats in one row

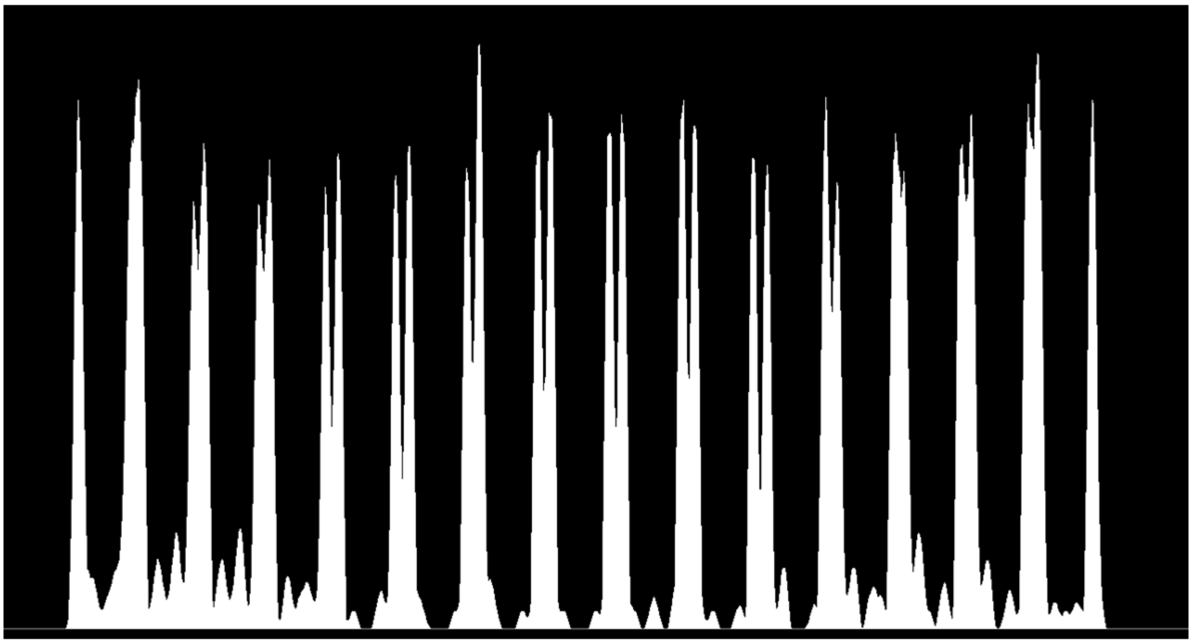

Figure 10. The projection of the vertical edge

Then calculate the position of the peak points. Obtain the first and second order derivative of the signal after filtering operations. The positions of the peak point S_{peak} are on the points satisfy the following conditions: the value is greater than average of the original signal; the first order derivative is zero; the second order derivative is negative. Formula is same as the (13).

Here we calculate the number of the pairs of peaks close to each other first, then use the average instead of the original value, finally got the best position to horizontal split.

$$\mathrm{S}^{\mathrm{c}}_{\mathrm{peak}}(\mathrm{k}) = \left(\mathrm{S}_{\mathrm{peak}}(\mathrm{i}) + \mathrm{S}_{\mathrm{peak}}(\mathrm{i}+1)\right)/2 \quad if(\left|\mathrm{S}_{\mathrm{peak}}(\mathrm{i}) - \mathrm{S}_{\mathrm{peak}}(\mathrm{i}+1)\right| < \mathrm{D}_{\mathrm{avg}}) \tag{17}$$

3. **Experimental results.** We evaluate the performance of the proposed algorithm with each key steps. Figure 11 is the real image in the hall monitoring. The segmentation result of horizontal orientation is shown as Figure 12, and most of the peaks have two extreme value points, it is result from the left and right edges of adjacent seats.

Aiming at the problem of seat area calibration which is used to statistic attendance rates by video surveillance, a seat position calibration algorithm based on improved edge operator and gray-level projection is proposed. The method introduces the improved Canny operator to detect the seat edge.

Firstly Bilateral filter is used to eliminate the noise while preserving edge of the image.

Secondly the preliminary horizontal and vertical edges are extracted respectively by using Sobel operator.

Finally, get the horizontal and vertical edge image intact through the non-maximum Suppression and double-threshold processing. Do horizontal project for horizontal edge, then isolated the best segmentation position from the projection sequence. Do vertical project for vertical edge, then isolated the best segmentation position from the projection sequence. Finally, the task of automatic marking of all seating area is successfully fulfilled.

FIGURE 11. Image of the movie hall

4. **Conclusion.** In this paper, we present a seat position labeling algorithm based on improved edge operator and gray projection with the improved Canny operator to detect the seat edge. The proposed algorithm includes: removing the noise through bilateral filtering; extracting the primary horizontal and vertical edges respectively; calculating the vertical projection of the vertical edge for each row of seats and isolate the best optimal seat partition position for each row of seats. The experiments on the real image, the proposed algorithm performs well. This proposed algorithm can be used on the intelligent monitoring.

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Figure 12. Segmentation result of horizontal orientation

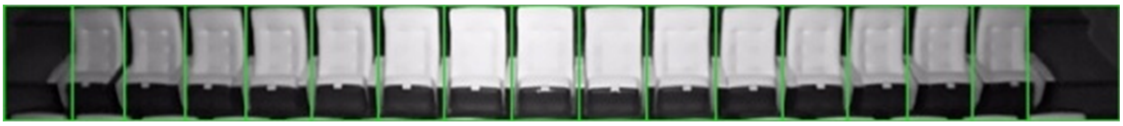

Figure 13. Segmentation result of single row