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CAR ANTI-BLOOMING METHOD BASED ON VISIBLE AND INFRARED IMAGE FUSION

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МЕТОД БОРОТЬБИ З АВТОМОБІЛЬНИМ ОРЕОЛЬНИМ ЕФЕКТОМ НА ОСНОВІ ЗЛИТТЯ ВИДИМОГО ТА ІНФРАЧЕРВОНОГО ЗОБРАЖЕНЬ

Purpose. To improve the safety performance at the night driving, this paper researches new car anti-blooming method.

Methodology. According to the characteristics of the color space transformation, the YUV and IHS algorithms were used to dispose visible light image and infrared image, and extract visible light image luminance component and infrared image information by wavelet transform to obtain the new luminance component. Then, the disposed image undergone inverse transformation and fusion disposing to gain new image, and give the detail calculation and disposing function.

Findings. The results of the car headlights image gathering at night and image processing show that the visible light and infrared image fusion processing algorithms can eliminate anti-blooming phenomenon and retain the image details, which can effectively weaken the anti-blooming effect.

Originality. The color space transform and wavelet fusion algorithm, IHS and wavelet transform fusion algorithm can better improve the image spectral distortion of car headlights at night, at the same time, YUV transform and wavelet transform fusion algorithm can obtain better edge information. This method is a new technology in the car research field.

Practical value. The proposed algorithm can be applied to automobile safe driving, and has a high application value.

Keywords: *anti-blooming, visible light, infrared image, image fusion algorithm, IHS transform, YUV transform, wavelet transform*

Introduction. When driving at night, improper use of headlamps can produce blooming phenomena, which causes traffic accidents if drivers cannot see roads in short time. According to United States National Highway Traffic Safety Administration (NHTSA) statistics, although night driving accounts for only one-fourth of the total road traffic, one-second of traffic accidents occur at night in the rate of 70% [1]. Except for drunk driving and fatigue driving, headlight blooming is another important factor that causes accidents at night. In order to eliminate the traffic accidents caused by blooming phenomenon, planting plants or installing anti-corona plates in median barrier of highway or rapid urban main road is simple and effective. However, most of the roads do not take the appropriate action under limited conditions. In order to improve the safety of driving at night, auto anti-halation draws the attention of scholars and engineers. Auto manufacturers have install night vision infrared instrument [2] in high-end cars such as Audi A8L or Cadillac DTS to eliminate auto halation phenomena.

According to the principle of infrared thermal imaging, higher temperatures radiate infrared imaging more easily and it is not sensitive to visible light. So infrared images can ensure drivers cannot be affected by the headlights of the vehicle on the opposite. Nevertheless, it has problems of single color and lack of important details (such as color and license number of vehicles, road conditions etc.)[3]. By two road CCD camera, researchers use different integration time to synchronously collect image from the same scene, with short integration time channel gets more information in the bright part of image, and with long integration time channel gets more image information of dark part, with pixel brightness shuffling or linear weighted synthesis method gets a video signal with wide dynamic range, which obtain some results of anti-blooming, but it cannot completely eliminate blooming phenomenon[4].

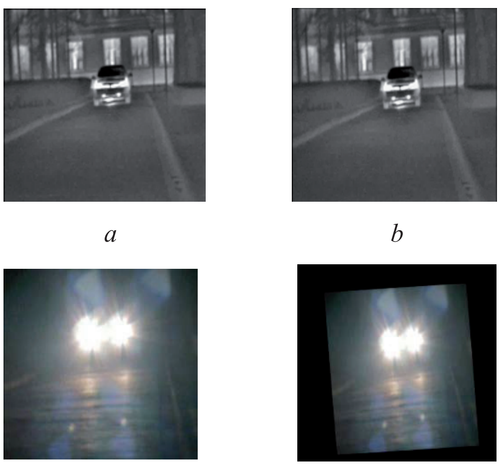
The existing anti-blooming methods have advantages and disadvantages, but none gets the desired result. This paper presents an anti-blooming method of visible and infrared images fusion to solve the disadvantages of existing method. The images obtained from visible sensor are clear and vivid. However, it is poor in anti-interference and night imaging capacity; infrared sensor can identify hot target by detecting temperature differences between auto and background, which cannot observe target clearly at night, but it can display contour of target, so it affects the imaging effect by lack of details information [5]. Using complementary of different image features in visible and infrared images, two image-processing algorithms based on the combination of color transform and Wavelet transform are presented: IHS-Wavelet transform, YUV-Wavelet transform. The proposed methods combined visible and infrared image to a video with wide dynamic range to eliminate the blooming phenomenon.

Anti-blooming of visible and infrared image fusion theory. According to visible light sensors and infrared sensor night imaging characteristics and the image can be broken down into three components through color space transform, images color space transform is applied in visible light in the case of results without distortion. IHS transform is used in component I separately while retains the original image colors and textures, YUV transform is used in component Y while retain the two chrominance signal U and V of the original image. Wavelet transform is applied on infrared image and the lightness component to obtain low frequency component containing image contour information and high frequency component of image details in level. With the rule of low frequency component using average method or weighted average fusion and high component using absolute in large fusion, then wavelet inverse transform is applied on the new high and low component [6]. Finally, the new component with the other two components of the original image conduct inverse color space transform to obtain a result that both eliminate blooming and improve the fusion of image details.

The implementation process of anti-blooming based on visible and infrared images fusion. ***Image preprocessing.*** When shooting the image, although two video cameras in the same location, taking at the same time, it would still be affected by the actual environment, so that it cannot fully reflect all the information in the environment. In order to ensure the accuracy of anti-blooming image results, the collected images are pre-processed first. Formula (1) is applied in removing the image noise; the image template size is 3×3.

$$R_{i,j}=\frac{1}{n^2}\sum^{n}\sum^{n} I_{i,j}. \quad (1)$$

In (1), $R_{i,j}$ is pixel gray value after smoothing disposing, $I_{i,j}$ is gray value of each pixel in a smooth template, n^2 is the size of a smooth template. We use affine transform to obtain the result while taking infrared images as reference, according to characteristic points; we can gain registration image result after inverse transform. Fig. 1 is the image preprocessing result.



a b

c d

Fig.1. Image pre-processing: a – infrared image; b – infrared image after filtering; c – visible image; d – visible image after registration

Fig.1, *a* is original infrared image by using the infrared camera, fig.1, *b* is the processing results by using mean filtering processing method based on the original infrared image, fig.1, *c* is the original image by using the visible light camera, fig.1, *d* is the registration processing image results.

Visible and infrared image fusion method based on IHS-wavelet transforms. IHS transform is applied on visible image to extract component *I*. Wavelet fusion is used on infrared image and visible component to obtain the new component *I'*, then IHS transform is used on component *I'* and the chrominance components *H* and saturation component *S* of the original visible image to obtain the final result of image fusion [7]. The block diagram is shown in fig. 2.

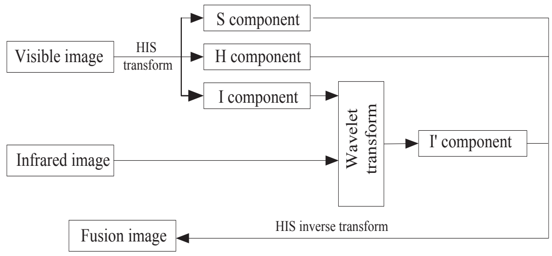


Fig.2. Image fusion process based on IHS-wavelet transform

The realization of the algorithm is given as follows.

(1) IHS transform is used on visible light images to separate the three channels and extract the brightness component, the chrominance component and the saturation component. Here, *I* indicates intensity component, *H* indicates hue component, *S* indicates saturation component, IHS transform is as follows

$$\begin{pmatrix} I \\ v_1 \\ v_2 \end{pmatrix}=\begin{pmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \\ \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{6}} & \frac{-2}{\sqrt{6}} \\ \frac{1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} & 0 \end{pmatrix}\begin{pmatrix} R \\ G \\ B \end{pmatrix}; \quad (2)$$

$$H=\tan^{-1}\left(\frac{v_2}{v_1}\right); \quad (3)$$

$$S=\sqrt{v_1^2+v_2^2}. \quad (4)$$

In (2–4), *R* represents RGB space red, *G* represents RGB space green, *B* represents blue; v_1 and v_2 respectively represent the color *S* component values.

(2) The spectral distortion of the image will be showed after the traditional IHS transform. To improve spectral distortion and eliminate blooming at the same time, retaining the original image under different frequency characteristics of information better, wavelet transform is applied on the lightness component of visible image and infrared image, then with the rule of low frequency components using mean values and high frequency components using absolute in large. *J* wavelet decomposition is applied on component *I* of the visible image and infrared image, formula (5) is their relation.

$$\begin{cases} C_j=H_mH_nC_{j-1} \\ D_j^H=G_mH_nC_{j-1} \\ D_j^V=H_mG_nC_{j-1} \\ D_j^D=G_mG_nC_{j-1} \end{cases}. \quad (5)$$

In (5), C_j, D_j^H, D_j^V and D_j^D respectively represent a low frequency component, horizontal, vertical and high frequency component in diagonal directions of the three directions in number *j* wavelet decomposition.

In the process of eliminating the blooming, the low frequency that represents approximation of the source image characteristics is equal to the original signal on a certain scale approximately. Image can be obtained from different sensors of the same scene; its low frequency isn't much difference in the part of approximation, so, we use low frequency component fusion method. Their calculation formula is expressed by formula (6).

$$C_j = \frac{\sum C_j^0(k)}{K}. \qquad (6)$$

In (6), K is the number of source images, C_j is the low frequency of fusion.

High-frequency information represent the most of characteristic of images, such as edges, texture, detail and other information, high frequency from the same scene obtained by different sensors are different. The main purpose is to enhance image detail during the process of high frequency information, which can be calculated by (7).

$$\hat{w}_{i,k} = \begin{cases} w_{i,k}^1 & , \quad \left|w_{i,k}^1\right| > \left|w_{i,k}^2\right| \\ w_{i,k}^2 & , \quad \left|w_{i,k}^1\right| < \left|w_{i,k}^2\right| \\ (w_{i,k}^1 + w_{i,k}^2)/2 & , \quad \left|w_{i,k}^1\right| = \left|w_{i,k}^2\right| \end{cases}. \qquad (7)$$

In (7), $\hat{w}_{i,k}$ is high frequency information in image fusion, $w_{i,k}^1$ and $w_{i,k}^2$ respectively represent the two images at va-rious scales of various components of wavelet coefficients [8]. Through different fusion rules, we can obtain new high and low frequency components, the brightness component in image will be decreased, then we can conduct wavelet reconstruction to obtain a new component I', which can be cal-culated by (8).

$$C_{j-1} = H_m^* H_n^* C_j + H_m^* G_n^* D_j^H + G_m^* H_N^* D_j^V + G_m^* G_n^* D_j^D \,. \qquad (8)$$

In (8), H is low-pass filter, G is high-pass filter, H^* and G^* respectively represent conjugate transpose matrix of H, G, m and n respectively represent the line and rank, j is wavelet decomposition level.

(3) Now the displays used RGB color standard, so, we need to be reconstructed by IHS inverse transform to obtain RGB images.

$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & \frac{-1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & \frac{-2}{\sqrt{6}} & 0 \end{pmatrix}. \qquad (9)$$

The final image we get is anti-blooming fusion image based on IHS transform and wavelet transform.

Visible and infrared image fusion method based on YUV-wavelet transforms. In the space of YUV color, each color contains three signal components, one is brightness signal Y and the other two are chrominance components U and V. Brightness is a feeling of strength, strength can be changed without affecting the color. Intensity and chromaticity are separate. We can come to that the image is a gray-scale if it only has the intensity signal Y and do not have chroma signal components U and V. Three signal components are combined to create a full color image. Wavelet transform algorithm based on YUV presented in this paper is to describe a process to get image fusion.

The process is that Y brightness component attracted from visible image through YUV transform conduct wavelet transform with infrared image to get a new Y', then YUV inverse transform is used on Y', U and V form original visible image [9].

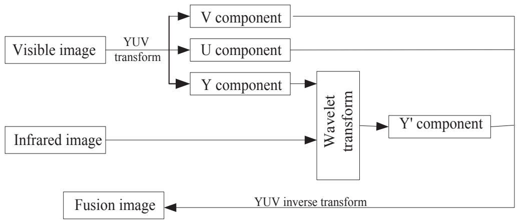


Fig.3. Image pre-processing

The realization of the algorithm is as follows.

(1)YUV transform is applied on visible light images after registration to get the Y, U and V components. Formula (10) is YUV transformation.

$$\begin{cases} Y = 0.299R + 0.587G + 0.114B \\ U = -0.1687R - 0.3313G + 0.5B + 128 \\ V = 0.5R - 0.4187G - 0.0813B + 128 \end{cases}. \qquad (10)$$

In (10), Y is the image luminance; U and V are the image chrominance.

(2) Wavelet transform is used on Y component and infrared image in order to obtain their own low frequency and high frequency(wavelet DB2, scale select option 2), using the rule of low frequency weighted average and high frequency components absolute in large. The fusion of low frequency and high frequency components can be obtained by wavelet inverse transform to get Y' component.

Since high-frequency fusion rules of wavelet transform based on HIS are mentioned above, so we do not need to describe it anymore. Using the weighted average method in low frequency components, setting the changed Y component is VY, infrared image is IR, $Y' = w1 * V_Y + w2 * IR$Y. The key is choosing the right weight ($w1$,$w2$) in two components of the weighted average, taking $w1$=0.1~0.9, $w2$=1- $w1$. The result is best when w1=0.5, w2=0.5.

(3)The image fusion is obtained through YUV inverse transform about the Y' and components U and V of the original image.

$$\begin{cases} R = Y + 1.402(V - 128) \\ G = Y - 0.34414(U - 128) - 0.71414(V - 128) \\ V = B = Y + 1.772(U - 128) \end{cases}. \qquad (11)$$

In (11), Y is luminance of image, U and V is chrominance of image.

The final resulting image is anti-blooming fusion image based on YUV transforms and wavelet transforms.

Experiment results and analysis. In order to verify the effectiveness of algorithm, we complete process of image fusion based on five algorithm, such as traditional YUV transform, IHS transform, wavelet transform, IHS-wavelet and YUV-wavelet transform which presented in this article, the specific image processing results are shown in fig. 4.

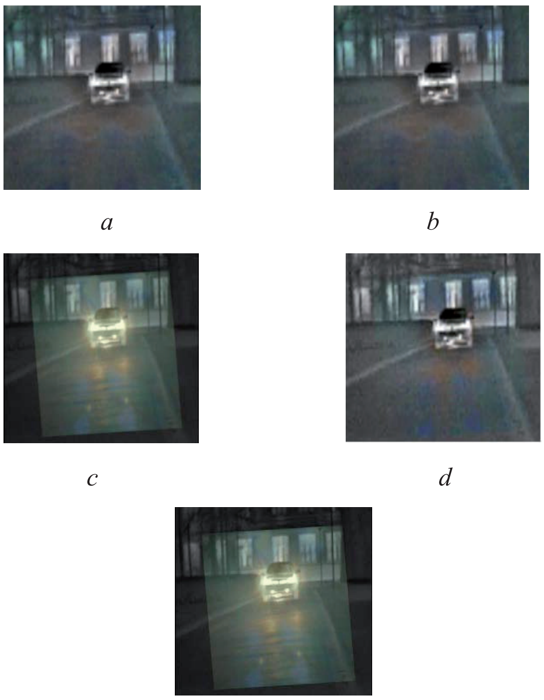


Fig.4. Experimental results: a – IHS transforms; b – wavelet transform; c – YUV transform; d – IHS-wavelet; e – YUV-wavelet

Fig.4, *a* is the processing results that IHS transform removes the halo phenomenon, but there is a clear color interference. Fig. 4, *b* is the wavelet transform processing results, we find the wavelet transform cannot eliminate the halo phenomena completely, but spectral distortion is not showed. Fig.4, *c* is the processing results that YUV transform eliminate halo phenomena, but the stitching traces are too obvious. Fig.4, *d* is the HIS and wavelet transform processing results that, the results show this kind method not only eliminate the halo phenomenon but reduce distortions in the image color, and it can retain the spectral information of the image at the same time better. Fig.4, *e* is the image after YUV-wavelet, the effect of anti-blooming is improved and driving environment is clear.

To analyze the results of image process objectively, we introduce four image evaluations to do further assessment, they are entropy, average gradient, standard deviation and Root-mean-square (RMS) error [10].

(a) Entropy. The size of entropy reflects amount of information, the larger entropy, and the better fusion effect. Their calculation function is (12).

$$H=-\sum_{i=0}^{L-1} p(i)\log_2 p(i). \qquad (12)$$

In (12), H is the entropy of the image, $p(i)$ is the distribution probability of the gray, L is the total number of gray level.

(b) Average gradient. Average gradient reflects the minute details in the image contrast and texture changes and it also reflects the clarity of the image, larger average gradient show the fused image more clearly, its formula is shown in (13).

$$\bar{D}=\sum_{i=1}^{M}\sum_{j=1}^{N}\sqrt{(\Delta I_x^2+\Delta I_y^2)/2MN}. \qquad (13)$$

In (13), $\bar{D}$ is the average gradient of the image, ΔI_x and ΔI_y respectively are first order difference score in x and y direction under pixels i and j.

(c) Standard deviation. Standard deviation reflects the intensity of each pixel of the image relative to the gray value of the discrete case. The standard deviation is large, gray level distribution is more dispersed. Gray-level fluctuation and gradient reflects the image detail, texture and edge information, the formula (14) is their calculation function.

$$STD=\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}(x_{ij}-\bar{x})MN}. \qquad (14)$$

In (14), STD is the standard deviation of image, x_{ij} and $\bar{x}$ respectively are the gray value and average gray value in point (i, j), MN is image size.

(d) RMS error. RMS error reflects the similarity of the fusion image and the image will be fused. It indicate the more similar of two images when the RMS error is small, the final image is closer to the original image, this also shows that most of the original information is preserved, image fusion effect is perfect, the formula (15) is their calculation function.

$$RMSE=\sqrt{\frac{1}{M\times N}\sum_{i=1}^{M}\sum_{j=1}^{N}[R(i,j)-F(I,J)]}. \qquad (15)$$

In (15), $RMSE$ is the square error of image, $F(I,J)$ and $R(i,j)$ indicate point (i, j) gray, F is actual fusion image.

According to the evaluation criteria mentioned above, we need to evaluate the data result from image fusion contain the YUV transform, IHS transform, wavelet transform based on IHS and wavelet transform based on YUV. Table is evaluation results.

Table

The Objective Evaluation of Fusion Result

Method	Entropy	Standard deviation	Average gradient	RMSE rror
YUV	6.825	38.559	0.005	1.19%
IHS	6.816	28.872	0.010	1.13%
Wavelet	6.856	38.436	0.006	1.32%
HIS-wavelet	6.864	38.468	0.010	1.02%
YUV-wavelet	6.859	38.586	0.008	1.07%

From table, compared to IHS transform, entropy of HIS-wavelet algorithm has increased 0.6%, which was 0.5% higher than YUV transform; entropy of YUV-wavelet algorithm is increased by 0.6%, 0.4% higher than the YUV transform.

This situation indicate that the algorithm of combining two color space transform and wavelet transform algorithm have more information than a single transform algorithm. IHS-wavelet algorithm contains slightly more information than YUV-wavelet algorithm.

Compared to IHS transform, IHS-Wavelet algorithm is improved by 33% in standard deviation of the image, but it is not higher compared to YUV as well as YUV-wavelet algorithm, which shows that YUV-wavelet algorithm is much clear in the edge information of image.

Compared to wavelet transform, YUV-wavelet algorithm of wavelet transform is improved by 35% in average gradient, while IHS-wavelet algorithm of image is 22% higher than average gradient of YUV-wavelet algorithm, which shows that the former is much clear in image texture information than the latter.

Compared to wavelet transform, IHS-wavelet algorithm of image is reduced by 29% in RMS errors, it also lower than IHS transform by 11%; YUV-wavelet algorithm is reduced by 23% in RMS errors and 11% in RMS errors, which shows that both kinds of fusion algorithm can contain much more image information than single transform algorithm, and IHS-wavelet algorithm better.

According to the objective data of image analysis, IHS-wavelet algorithm is better than the YUV-wavelet algorithm in entropy, RMS error and much more suitable for eliminating the blooming problem on night car driving. But YUV-wavelet algorithm is much higher than IHS-wavelet algorithm on the standard deviation, which shows that the edge information of the image is much clearer.

From the complexity of analysis, wavelet transform image needs to transform each of the color channels. After wavelet transform combine with color space conversion, all we need to do is conducting wavelet transform between brightness of an image component and infrared images, thus reducing the operational time of the algorithm greatly, improving the speed of image processing at the same time.

Visible and infrared image fusion system. What the camera output is the number of frame dispersed in time, and each frame is similar to the still image divided into discrete rows and columns. Each unit is still described by the image pixels. Video can be seen as extensions to the still image. Videos are sequences taken on a regular interval. According to the persistence of vision of the human eye characteristics, frame rate should be more than 25 frames per second, it will appear flashing and feeling of discontinuity. In order to validate the efficiency and instantaneity of image fusion algorithm proposed in this paper, we develop a system fused by visible light and infrared image video. System hardware consists of infrared cameras, visible camera, frame grabber and PC. Fig. 5 is system chart. Software is implemented by VS2008 and OpenCV1.0 image gallery.

Visible and infrared image fusion system works as follows.

1. To capture the images transferred through visible light camera and an infrared camera with capture card.
2. To pre-process the images collected on a PC machine, then register the visible images.
3. To fuse two images registered.
4. Display fusion image.

Hardware platform. We choose XenICs Raven-384-P as infrared camera at a resolution of 384×288, and select WAT-231S color cameras as visible light cameras at a resolution of 737×575.Two video cameras are acquired to synchronize the images. Visible light camera and infrared camera should be set to internal and external synchronization modes. Visible light camera output signal and infrared camera input signal should be connected.

We select MV-8002 as frame grabber, which can capture information in double channel meanwhile, which is based on PCI, applied in a situation that need to deal with two channel images in real-time and high-speed, it has a high quality of image quality and stability. Image grabber will convert analogy video signals into digital format. Image data transmitted through PCI master burst mode. Data transfer rate can be as fast as 40MB/S during the image acquisition process. So it can transfer images to the computer's memory in real-time stably and do not occupy any more time. It gives processor more time to do image processing operations.

We choose Advantech IPC-610H, Intel Core I7 CPU, 8G DDR3 1600, 500GB hard disk and VGA interface display output. Let MV-8002 capture card into the computer's PCI slot, connect infrared camera with the corresponding port of visible light CCD camera by two video signal line, adjust the camera position and fixed, then finish the fusion hardware setup.

Video fusion analysis. Video fusion is a process that taking medium filter to each image when call-back each data in two images, then filter visible light image affine transformations and infrared image registration, and the visible and infrared images are fused after registration.

In the video fusion system, the button of “registration set” to set the feature points for image registration, obtaining images from two videos at the same time, using infrared image as the standard, and visible light images as image registration. There are five fusion methods to be chosen, which are YUV, HIS, wavelet fusion, YUV-wavelet transform and HIS-wavelet transform. Click fusion button to start video fusion, video display area shows fusion image. Fig. 5 shows the processing results of video fusion system.

Fig. 5, *a* is the original visible video, fig. 5, *b* is Infrared video, fig. 5, *c* is the last video we use the fusion disposing algorithm of YUV, HIS, wavelet fusion, YUV-wavelet transform and HIS-wavelet transform.

The video fusion results are consistent with simulating results; however, there is a larger difference in real-time image fusion.

The method is simplebased on YUV color space and HIS fusion, having fast processing speed of 30~40ms/frames to meet the real-time image fusion.

Method based on wavelet transform need to conduct wavelet transform to all of the three-color channels of visible image, and then fusion is applied with any channel separately. The fusion speed is 80~90ms/frames, whose fusion image is, not continue, and cannot meet the requirements of real-time image.

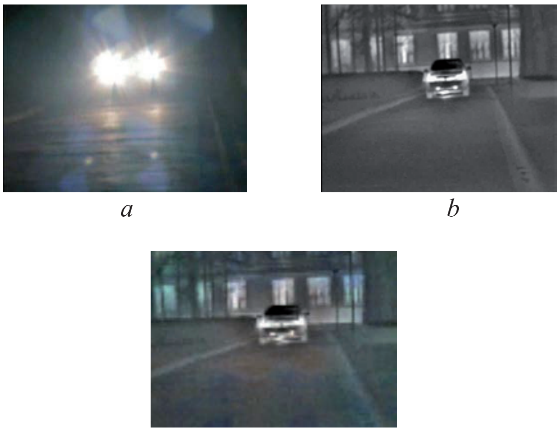


Fig. 5. The processing results of video fusion algorithm: *a* – visible video; b – infrared video; c – video after fusion disposing

Method combined the two color space transform of YUV and HIS with wavelet transform is such a process, first color space conversion is used on visible light images, then wavelet fusion is applied on the lightness component and the infrared brightness of the image to get new components, and the inverse color space transform is applied to obtain image fusion. Because there is only one color channel wavelet fusion, computation is smaller than wavelet transform. What we drawn from the experiment is when processing speed is between 40~50 ms/frames can meet 20~25 frames per second, and it can realize the real-time video fusion and get fusion effect better.

Conclusions. In order to overcome the blooming phenomenon of car when driving at night, using visible light sensors to collect the vehicle details such as color, license plate numbers, road conditions and infrared sensors to spot the car headlights halo region, two anti-blooming algorithm by combining color space transform and wavelet transform of visible light image and infrared image are presented. Through subjective evaluation of image processing results and data, the image processing algorithms based on the combination of wavelet transform and color space overcome the blooming problems, increasing the spatial resolution of the image, preserving image details. It turns out that algorithms presented can eliminate the impact of blooming on driving at night effectively.

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Мета. Дана стаття описує новий спосіб боротьби з ореольним ефектом для поліпшення показників безпеки при нічному водінні.

Методика. У відповідності до характеристик перетворення колірного простору використовуються алгоритми YUV і IHS для представлення видимого та інфрачервоного зображень, з яких, за допомогою вейвлет-перетворення складової яскравості видимого світла та інфрачервоного зображення, отримана нова складова яскравості, а потім виконується злиття та зворотне перетворення для здобуття нового зображення. Приведені детальні розрахунки та визначальна функція.

Результати. Результат, отриманий за допомогою збору та обробки нічних зображень фар рухомих автомобілів, показує, що алгоритм злиття видимого та інфрачервоного зображення може ліквідовувати ореольний ефект і, у той же час, зберегти деталізацію зображення.

Наукова новизна. Представлена алгоритмом перетворення колірного простору й вейвлет-злиття. IHS і алгоритм вейвлет-перетворення забезпечують поліпшення зображення зі спектральними спотвореннями від фар автомобіля вночі, у той же час, спільне використання алгоритмів YUV-перетворення та вейвлет-перетворення дозволяє отримати чіткішу інформацію. Цей метод є технологічною новиною для наукових досліджень в області автомобілебудування.

Практична значимість. Запропонований алгоритм може бути застосований в області автомобільної безпеки й має високе прикладне значення.

Ключові слова: *ореольний ефект, видиме світло, інфрачервоне зображення, алгоритм злиття зображень,*

IHS-перетворення, YUV-перетворення, вейвлет-перетворення

Цель. Данная статья описывает новый способ борьбы с ореольным эффектом для улучшения показателей безопасности при ночном вождении.

Методика. В соответствии с характеристиками преобразования цветового пространства используются алгоритмы YUV и IHS для представления видимого и инфракрасного изображений, из которых, посредством вейвлет-преобразования составляющей яркости видимого света и инфракрасного изображения, получена новая составляющая яркости, а затем производится слияние и обратное преобразование для получения нового изображения. Приведены детальные расчеты и определяющая функция.

Результаты. Результат, полученный посредством сбора и обработки ночных изображений фар движущихся автомобилей, показывает, что алгоритм слияния видимого и инфракрасного изображения может ликвидировать ореольный эффект и, в то же время, сохранить детализацию изображения.

Научная новизна. Представлена алгоритмом преобразования цветового пространства и вейвлет-слияния. IHS и алгоритм вейвлет-преобразования обеспечивают улучшение изображения со спектральными искажениями от фар автомобиля ночью, в то же время, совместное использование алгоритмов YUV-преобразования и вейвлет-преобразования позволяет получить более четкую информацию. Этот метод является технологическим новшеством для научных исследований в области автомобилестроения.

Практическая значимость. Предложенный алгоритм может быть применен в области автомобильной безопасности и имеет высокое прикладное значение.

Ключевые слова: *ореольный эффект, видимый свет, инфракрасное изображение, алгоритм слияния изображений, IHS-преобразование, YUV-преобразование, вейвлет-преобразование*

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