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Improved colorization for night vision system based on image splitting

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ABSTRACT

The success of a color night navigation system often depends on the accuracy of the colors in the resulting image. Often, small regions can incorrectly adopt the color of large regions simply due to size of the regions. We presented a method to improve the color accuracy of a night navigation system by initially splitting a fused image into two distinct sections before colorization. We split a fused image into two sections, generally road and sky regions, before colorization and processed them separately to obtain improved color accuracy of each region. Using this approach, small regions were colored correctly when compared to not separating regions.

Keywords: color night vision, image database, image fusion, night navigation

1 INTRODUCTION

We proposed an approach for a night navigation system based on a system[1] proposed by Hogervorst et al[2]. Our system was designed for terrestrial vehicle navigation in dark conditions and used color information from a public database of images to assign color information to an intermediate image. This image was obtained by combining two spectral bands of images, thermal and visible, in an effort to enhance night vision imagery. However, the fused image gave an unnatural color appearance. Therefore, a color transfer based on look-up table (LUT) was used to replace the false color appearance with a colormap derived from a daytime reference image. The reference image was obtained from a public database using the GPS coordinates of the vehicle. Using this approach, we were able to produce imagery acquired at night that appeared as if in the daylight.

We considered here an approach that depends to some degree on what is expected. For example, when driving a ground vehicle, a road is typically at the bottom of a scene, and the sky is at the top. We used this concept to aid the development of a passive system to improve safety while driving a ground vehicle at night. We split the fused image into two sections, generally road and sky regions, before colorization and processed them separately to obtain improved color accuracy of each region. It was not necessary to separate the regions precisely, only to separate the dominate region in terms of area. Therefore, separating the image could be done quickly, which is suitable for real-time operation.

Another problem in the original system was due to the fused and database images not being registered perfectly. Highly accurate registration was difficult because of the different sensors, conditions, times, and positions used. Therefore, small objects were sometimes completely missed because the colormaping process was generally dominated by two large groups of colors. Since the new approach increased the accuracy of the colors, some objects were more visible.

2 APPROACH

Figure 1 shows the system architecture of the night vision colorization system using a public database[1]. The system has four inputs and two outputs. Two of the inputs are from cameras, and one from a GPS sensor. There is also an input that receives images from a public database. The two outputs consist of a connection to a public database that sends requests for images, and the display of the final result of the night scene. The two cameras provide images of the same scene with different sensors. In our case, one camera was a DRS Technologies Tamarisk® IR thermal camera with 320 x 240 pixel resolution and a field-of-view (FOV) of 40 degrees. The other camera was an Everfocus EQ700, which amplifies light over spectral range from 400 to 800 nm. It has an analog video signal output at rate 30 fps with a resolution of 640 x 480 pixels. These cameras provided responses for two distinct spectral regions.

We used a Garmin GPS 18x sensor to gather location data that is used to identify specific images needed from a public database. By providing location and angle information, requests can be sent over a standard internet connection, and a Google Street View image returned at a specific location and angle[3,4]. Acquiring images at specific locations allowed us to extract colormap information to enhance our real-time fused images.

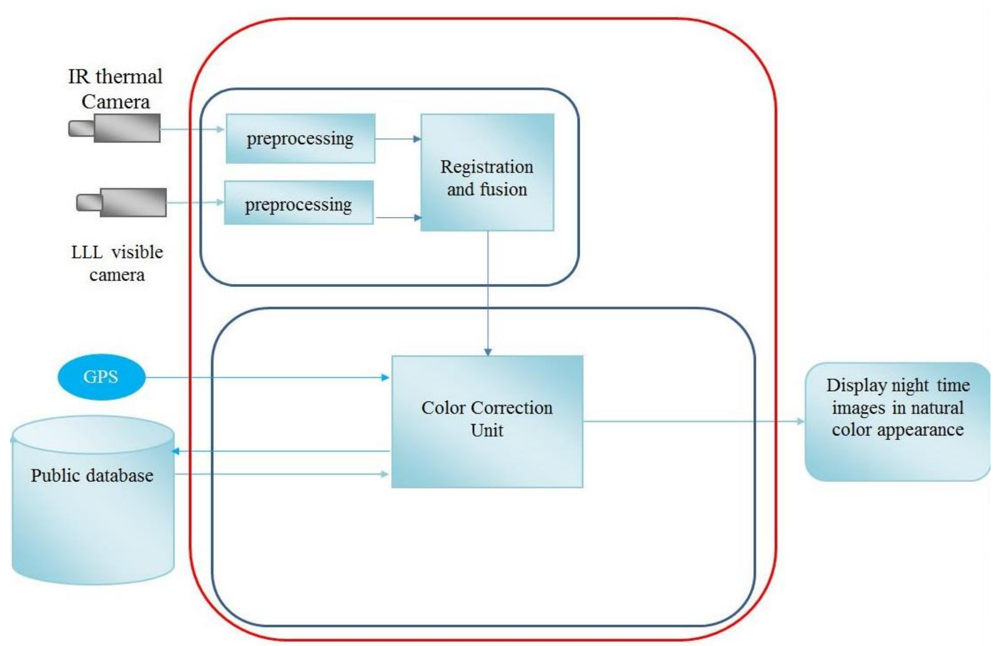


Figure 1. System architecture.

Preprocessing operations adjust image values, aligns images, and then combines them prior to colormap adjustment. Acquired video by the visible camera in a low light condition is usually noisy; therefore, BM3D algorithm has found to work remarkably well when compared to other denoising filters[5]. It assumes constant white noise so that only a single value of the noise standard deviation σ needs to be provided. Since the camera is often used under the same condition, we used a value of σ = 20 based on 8-bit integer image values in all our work which seemed to work well. The two registered images were fed into a dual band image fusion section which maps the thermal images into the R channel of an RGB system and visible images into the G channel, and sets the B channel to zero. The resulting false-color fused image **wa**s then fed to a color correction unit to replace the unnatural colors with the correct colors using a colormap transfer method. The new colormap was derived from an acquired Google Street image according to the GPS location of the vehicle position. Location data from the GPS sensor was put into a format of a request to Google Street View, and a single image was returned for each request. The request for a new image is required when the scene changes appreciably, but was set to update periodically in our case.

A color mapping technique[6,7] was introduced by as a real time colorization process based on color remapping and has been efficiently implemented as a lookup table transform[8,9]. The general procedure is to:

1. Convert the false-color image to an indexed image where a single index is assigned to each pixel. Each index value represents an RGB-value in a color LUT. In our case, the color lookup table contains only combinations of R and G values.

2. Derive the natural color equivalent for each index by locating pixels in the false-color image with a particular index and finding the corresponding pixels in a registered daytime image of the same scene.

3. Calculate the average of this group of pixels in *lαβ* color space. This means the RGB values are transformed to decorrelated *lαβ* values. This ensures that the computed average color reflects the perceptual average color[2].

4. Convert back to RGB space and assign values a new color lookup table for the false indexed image.

5. Replace the luminance of the corrected image with a grayscale version of the false-color image.

Figure 2 shows example images of the process.

A significant issue when using Google Street View images for the colormap is the registration with the fused image[10]. We used mutual information (MI) as a metric for alignment for registration between the two types of imagery. However an imperfect registered reference image will be created to derive the final colormap because of alignment error and geometrical effects. Because large regions of the same or similar color many dominate the colormap, small objects may acquire the incorrect color. This is significant because small objects may represent important features in an image. For example, small objects that have the same intensity values of large areas in the target image will be adopt the color of the large region. If a small region is within the large region, it will be difficult to observe. If it is not within the large region, it will adopt an incorrect color. Often, small regions will adopt the color of large regions.

Therefore, we split the false-color and reference image into two regions in exactly the same way. Since we are ultimately interested in real-time operation, we required a simple way to split the image. Many segmentation methods are be computationally expensive, so we considered an approach that depends to some degree on what is expected. For example, when driving a ground vehicle, a road is typically at the bottom of a scene and the sky is at the top. These features usually are represented by large areas of a narrow band of colors. Therefore, we split both the target image and reference image into two parts each with a horizontal line placed near the center of the vertical axis. In a general way, this procedure isolates the regions of dominant colors. It was not necessary to separate the regions precisely, only to separate the dominate regions in terms of color. Using this approach, the sky and its relatively narrow range of colors represented the dominant color in the upper part of the split image, while the road represented the dominant color in the bottom part. This way, any feature that falls outside of the dominant color region will not get colored by that color, even if it has same pixel intensity values.

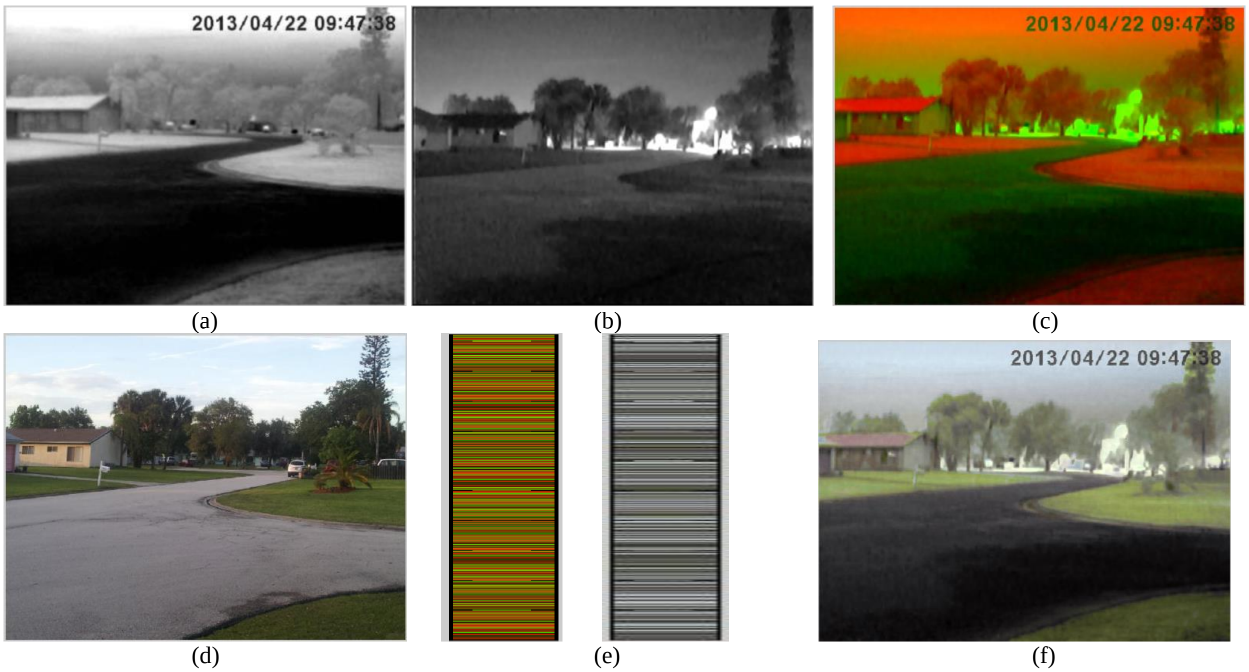
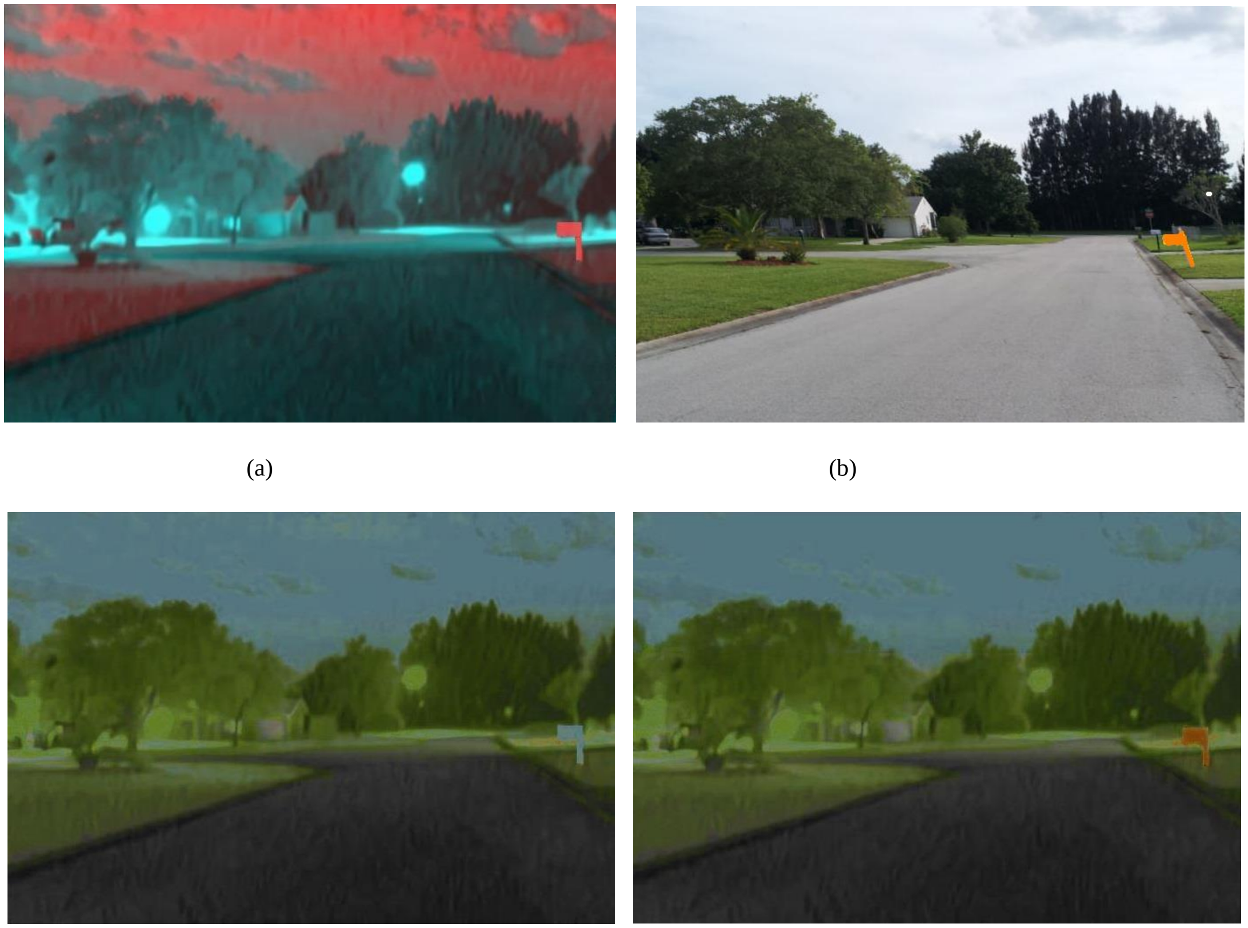


Figure 2 Images of same scene used in example (a) preprocessed IR image (b) preprocessed visible image (c) fused false color image (d) reference image (e) false-color (on left) and derived (on right) colormaps (f) final result.

3 RESULTS

Our approach is designed to preserve color information of small regions. To evaluate our approach that is based on isolating dominant color regions, we used an image with a small object with intensity values that fall in a range of intensity values of a dominant color area. The image in Fig. 3a is a false-color image formed by combining thermal and visible images as described earlier. Figure 3b is the reference image from where we extracted the colormap. The result when the conventional approach is used to correct the false-colored image is shown in Fig. 3c. In this case the mailbox was colored the same color as the sky. The result of the proposed method in shown in Fig. 3d. By applying the new image splitting scenario described in the previous section, the mailbox appeared similar to the correct color and much different from the color of the sky.



(a) (b)

(b) (d)

Figure 3. Example (a) false-color fused image (b) registered Google Street View image (c) colorized result using conventional method (d) colorized result using proposed method.

4 CONCLUSION

By splitting both fused and daytime images horizontally into two sections (generally road and sky regions), we created two colormaps. We processed these two sections separately to obtain improved color accuracy of each region. It was not necessary to precisely segment large regions of color. When images typical of road navigation were used separating the image into two with a large region was possible.

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