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Color night vision system for ground vehicle navigation

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ABSTRACT

Operating in a degraded visual environment due to darkness can pose a threat to navigation safety. Systems have been developed to navigate in darkness that depend upon differences between objects such as temperature or reflectivity at various wavelengths. However, adding sensors for these systems increases the complexity by adding multiple components that may create problems with alignment and calibration. An approach is needed that is passive and simple for widespread acceptance. Our approach uses a type of augmented display to show fused images from visible and thermal sensors that are continuously updated. Because the raw fused image gave an unnatural color appearance, we used a color transfer process based on a look-up table to replace the false colors with a colormap derived from a daytime reference image obtained from a public database using the GPS coordinates of the vehicle. Although the database image was not perfectly registered, we were able to produce imagery acquired at night that appeared with daylight colors. Such an approach could improve the safety of nighttime navigation.

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

1. INTRODUCTION

Operating in a degraded visual environment due to darkness can pose a threat to navigation safety. Systems have been developed to navigate in darkness that depend upon differences between objects such as temperature differences or reflectivity at various wavelengths. Such systems typically use a combination of passive and active sensors to discriminant between objects. However, adding sensors increases the complexity of a system by adding multiple components that may create problems with alignment and calibration. An approach is needed that is passive and simple for widespread acceptance. Usually, inputs consist of a small number of images captured by different sensors. The process differs from system to system but often input images are fused into a false color image. Displaying three-band natural color images has been the goal of some recent approaches, and color transfer using a reference color image such as a synthetic, daytime, or any other image source has been a common solution [1-6].

This paper presents a night navigation system based on transferring colors from scenes taken at corresponding locations in daytime. The proposed system uses a publically available image database as a reference for color imagery, which is demonstrated with Google Street View. Colormap transfer was based on a look-up table (LUT) derived from a daytime reference image obtained from a public database using the GPS coordinates of the vehicle. The main idea is to colorize the false color image using a public image database that corresponds to the same location.

2. THE PROPOSED SYSTEM

Google Street View is the largest publicly available collection of images recorded from a driver's perspective, covering many different countries and scenarios. It can be a valuable tool for developers of vision-based assistance systems because images in Google Street View can be used as reference images to color night imagery. Figure 1 shows the proposed system architecture of the night vision colorization system using a public database.

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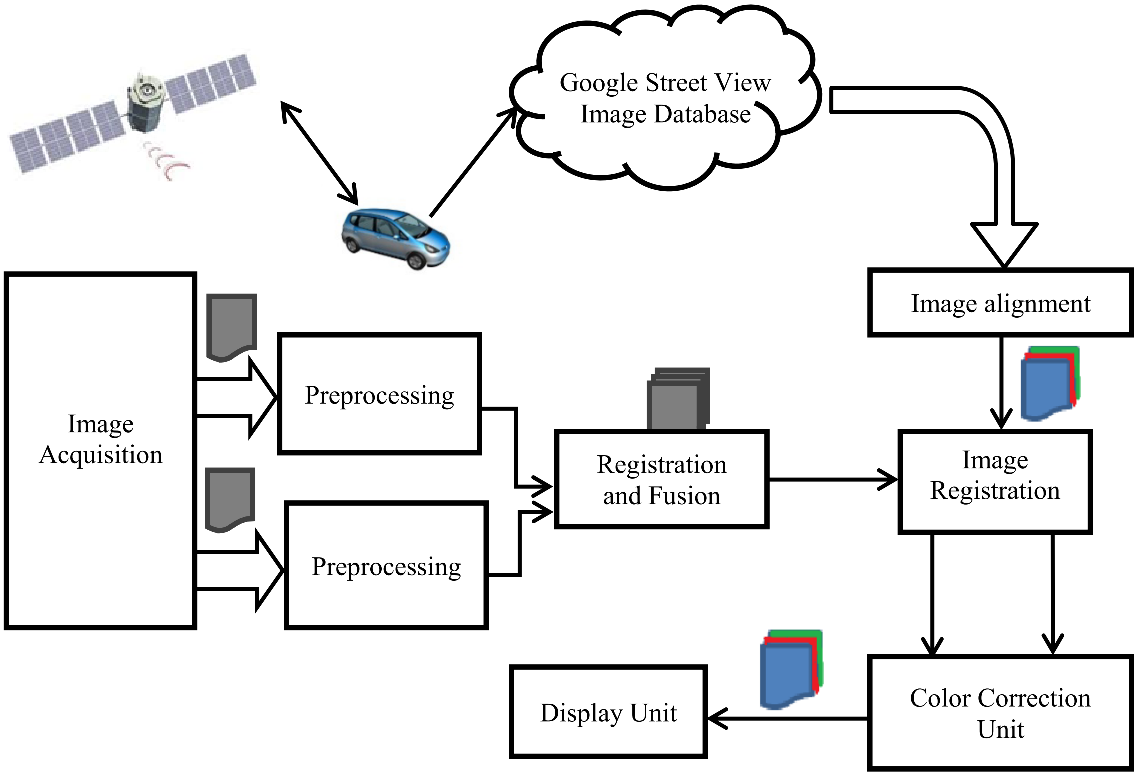

Figure 1 The proposed night vision system.

The system has four inputs and two outputs. Two of the inputs are from cameras, one from a GPS sensor and the other 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 GPS sensor to gather location data that is used to identify specific images needed from a public database. We used a Garmin GPS 18x sensor with a USB connection for connection to a computer. The device provides location data at a rate of 1 Hz and has an accuracy of less than 15 meters when stationary. Google Maps is a public database that provides 360 degree image data from points around the world and can be easily accessed. By providing location and angle information, requests can be sent over a standard internet connection, and a Google Street View image can be returned at a specific location and angle [7, 8]. Acquiring images at specific locations allowed us to extract colormap information to enhance our real-time fused images.

The image preprocessing section plays an important role that adjusts image values, aligns images, and combines them prior to colormap adjustment. This section uses two cameras from different sensors as inputs and produces a single false-color image as an output. Images acquired from the cameras cannot be directly combined for several reasons. For example, video acquired by the visible camera in a low light condition is usually noisy; therefore, a denoising algorithm was used to enhance the output of that camera. A video implementation of a BM3D filter was used as the noise reduction filter [9]. The BM3D algorithm has found to work remarkably well when compared to other denoising filters. 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 $\sigma = 20$ based on 8-bit integer image values in all our work, which seemed to work well. The thermal camera was adjusted so that its output was set to the darkest values for the warmest values, and white for the coldest.

The visible and thermal cameras were mounted on top of each other providing a fixed position difference between them. Even though there were differences in parameters such as position, resolution, and their FOVs, these differences did not change. Therefore, an affine transformation was adopted to obtain registered images. The two registered images were fed into a dual band image fusion section that 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.

The fused image from the preprocessing stage had unnatural colors and needed to be replaced with the correct colors. In the color correction unit, the false colormap of the fused image was swapped with an improved colormap for display of the final image. The color correction unit used the GPS sensor and false-color image as inputs as well as the output of the public image database. One output is for requests made to the public database, and the other is the final fused image with an improved colormap. 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 this was set to update periodically in our case.

The main function of the color correction unit is to extract a color map from the reference images and apply it to the false-color fused image. A color mapping technique was introduced by [10,11] as a real time colorization process based on color remapping. It has also been efficiently implemented this as a lookup table transform [12,13]. The main issue of using Google Street View image is the registration with the false-color image. These two types of images belong to different modalities which make the registration process difficult. Therefore, used mutual information (MI) as a metric for alignment for registration.

3. RESULTS

This section presents experimental results obtained from the proposed system. Figure 2 shows a set of images from a single frame of video from the input cameras as well as the corresponding colorized result. Figures 2a and 2b show the denoised visible and thermal images from the input cameras respectively, and Figure 2c shows the fused image with false colors. The reference Google Street View image determined from the vehicle's location is shown in Figure 2d. The image in Figure 2e is the Google Street View image registered to that of the input scene. The colormap was determined from this image and applied to the false-color image which resulted in the image in Fig. 2f.

4. CONCLUSION

We demonstrated that a false-color image generated from a fusion of thermal and visible video can be colorized using the colormap of a Google Street View image. In our experiments, the registration between the fused and reference images were aligned by using a straightforward algorithm based on MI. Due to the computational demands of real-time image registration, we emphasized speed over performance of registration.

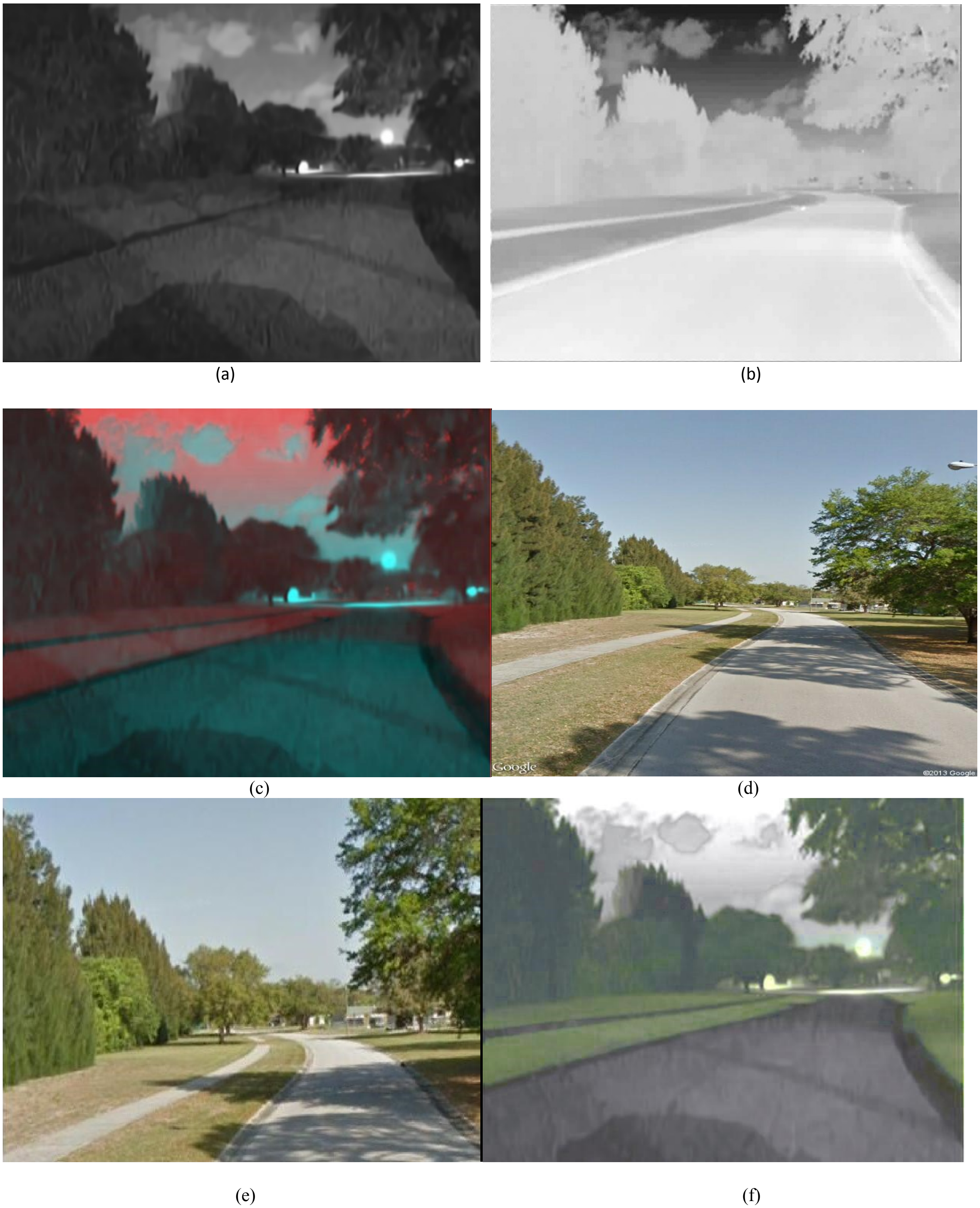

Figure 2 Example results (a) singe frame from visible camera (b) singe frame from thermal camera (c) fused image (d) Google Street View image (e) registered Google Street View image (f) colorized result.

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