Noise Cancellation Methods for Wearable Devices using Microprocessors

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Abstract –
In this paper we propose noise cancelation methods for wearable devices which can be used for sight impair people. In the last decades, a variety of wearable devices have been developed to support blind people in their daily lives. These devices assist blind people to navigate to avoid obstacles while walking in both indoor and outdoor environments. The wearable devices have some reasonable requirements such as small sizes, light weight and low power consumption. They should work independently as personal-used devices. They also should work well as the users walk or run. These kinds of motion can cause many types of noises to the systems such as: camera motion, illumination changes. The proposed methods employing microprocessors reduce the effects of these noises. A real system is built and experimental results are provided to clarify the problems.

Keywords - *Noise Reduction; Monitoring; Microprocessors;*

I. INTRODUCTION

A. Motivation

Video monitoring has been one of the most active research topics in computer vision area [1-4]. Systems employing captured video as input signal have a wide range of applications such as for crime prevention [5], traffic control [6], dangerous prediction and detection [7], and monitoring children and elderly people at home [8][9]. Video monitoring entices many researchers who mainly concentrate on investigate effective methods for extracting useful information in video databases.

Electronic components become more common with the cost reduced and more functions integrated that motivate to develop real devices to assist people to have better life. One of the interesting topics is wearable device for visually impaired people. Visually impaired people, who cannot see well, need to be supported to have safety walking. Many research results and products have been published to support visually impaired people. Most of the work is based on ultrasonic distance sensors and microprocessors [10][11]. However, the current work cannot provide all necessary information for the user.

Since cameras and microprocessors have been well developed, researchers are focusing on creating vision systems to help visually impaired people [12]. A common vision system with input data from cameras processes the video information, and provides output with visual display or other significant notifications such as tone or vibration.

When the user who wears the system walks, the vision system could be affected by some kinds of noise from surrounding environments and from the device itself. There exist a lot of results of noise cancellation methods mentioned to solve the problems. Noise effect cannot be removed completely from the systems. In our work, we expect to investigate a better noise cancellation method to enhance the system quality and to supply precise information for the users.

B. Related Work

In recent decades, a variety of portable or wearable navigation systems have been developed to assist blind people during navigation in known or unknown, indoor or outdoor environments. Categorizations of the systems based on their various features and performance parameters are summarized in [5],[13]. In these categories, there are some remarkable devices, for instance, a wearable device offering new sensing abilities with a multi-sonar system is shown in [14]. A wearable activity device and a walking assistant robotic system based on computer vision and tactile perception have been proposed in [15][16]. In these devices, noises in input signals have a dramatic effect on outputs' quality. There are many types noise effects can be listed as follows: dynamic obstacles and moving users, invalid ranges, scatter effects, color sensors, recording media, quantization errors, management and storage of the data and other optical factors [16-20].

In the vision-based systems, data from wearable devices normally need to be analyzed and processed to give trustable warnings or navigations to the users. In the conventional theory, noise reduction can be considered as a major factor to make a suitable decision. The noise may come from ambient environments when illumination changes, obstacles move or the users walk. Hence, there have been a variety of methods to cancel the noises for recent years. A novel fuzzy 3D filter designed to suppress impulsive noise in color video sequences has been shown in [21]. Additionally, a soft-threshold scheme is proposed to reduce compression noise with content-based noise level estimation [22]. There has been video de-noising framework based on online 3D spatio-temporal sparsifying transform learning, which are particularly useful for processing large scale or streaming data [23]. The block-based motion estimation (ME) and motion compensation (MC) techniques are widely used in modern video processing algorithms and compression systems. The great variety of video applications and devices results in diverse compression specifications, such as frame rates and bit rates [24].

In this paper, a compact wearable device employing microprocessors to support the visually impaired people is proposed. The system performance meets generally required criteria such as accurate prediction, fast computing ability, small storage and low-power consumption. Moreover, an algorithm to deal with the above noises has been introduced. The main contributions in this work are summarized as follows:

1. A new noise reduction method is proposed for wearable devices to assist disabilities.
2. The system has a real-time processing ability because of the low-time consumption of microprocessors.
3. A real device has been designed and implemented to check performance of the proposed algorithm effectively

The remainder of this paper is organized as follows. The Proposed System is addressed in Section II. Experiments and Results are presented in Section III and Section IV, respectively. Conclusions and suggestions for future work are addressed in Section V. The list of key notations used in this paper is provided in Table I.

Table II Key Notations

$I^{t}_{(x,y)}, I^{t+1}_{(x,y)}$	Current color image at time t, t+1.
$C^{t}_{(x,y)}, C^{t+1}_{(x,y)}$	Converted gray scale image at time t, t+1.
T	The Homography matrix
$D^{t+1}_{(x,y)}$	The absolute different image
$E^{t}_{(x,y)}$	Final error image

II. THE PROPOSED SYSTEM

A. Hardware Architecture

A neckband wearable device is chosen to be implemented which is suitable for the users when they walk or work in both indoor and outdoor environments. The kind of hardware can be split into parts. The system diagram is shown in Fig. separately with camera, memory, CPU, battery, monitor screen, neckband-head phone).

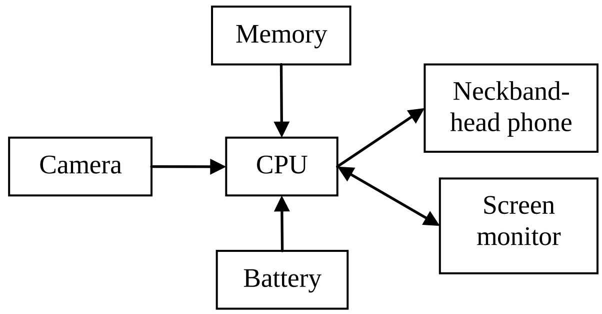

Fig 1. System Diagram

The main part of the system is the processing board. The video is captured by the camera module and is transferred to the processing board by a light weight cable. The operating system, data and software algorithm are stored in the storage memory part. All the electronic elements of the system are supplied by power supply module. When the system is turned on, the software algorithm will run and send the results to the LCD screen module and finally make alarm sound notification for the blind people.

B. System Analysis

This section, we propose methods to reduce noise when the system works based on user motion and color information from the captured image frame. The moving object in our system is human. In reality, the moving objects could be more broadly such as moving bicycle, motorbike, car or the other objects. The propose method is separated to three main parts: (i) Remove statistical noise, (ii) Motion blur noise cancelation and (iii) Correct moving object based on color changing.

The main objective of the first step (remove statistical noise) is to reduce random noise of the environment, image sensor and to correct the illumination changes in the captured image. When the user walks, the wearable device also moves. Then, we apply the second step to decrease the effect of the user moving motion on the results by apply motion vector. Finally, in the third step we use color information to correct the final results. The flowchart of the software algorithm is presented in Fig. 2.

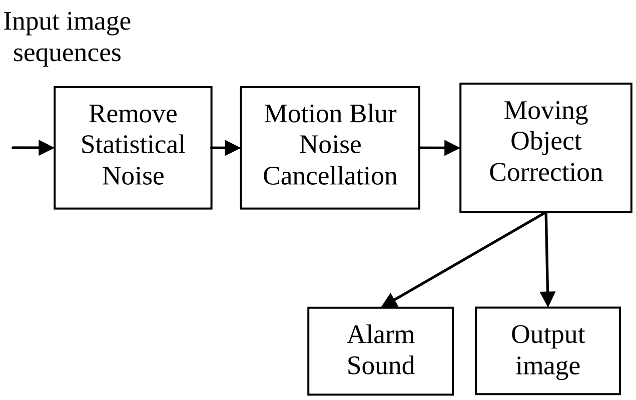

Fig. 2. The Flowchart of the Software Architecture.

Due to hardware limitations and real time process requirement, we apply simple but effective algorithm to reduce computation time. For the first step, when the camera is activated, the input image at current time t, $I^{t}_{(x,y)}$ will be converted to grayscale image $C^{t}_{(x,y)}$. In order to reduce random noise from outside environment, we apply Gaussian filter on the converted image.

When the user moves, the wearable device system could be affected by the motions. In this case, the background of the captured video is not longer static or unstable. This causes motion blur noise in the output image. In order to classify moving foreground object we have to deal with two kinds of motion, the ego-motion of the camera that equals to the user motion and the moving-object motions. In the case of non-static background, in order to figure out either which parts of the picture are changing or which parts are changing independently, the camera motion should be estimated [25].

Let $C^{t}_{(x,y)}$ and $C^{t+1}_{(x,y)}$ be two consecutive frames. The relationship between $C^{t}_{(x,y)}$ and $C^{t+1}_{(x,y)}$ can be presented ideally as shown in Equation (1) as

$$C^{t}_{(x,y)} = TC^{t+1}_{(x,y)} \qquad (1)$$

or

$$\begin{pmatrix} x_{t+1} \\ y_{t+1} \\ 1 \end{pmatrix} = \begin{bmatrix} t_{11} & t_{12} & t_{13} \\ t_{21} & t_{22} & t_{23} \\ t_{31} & t_{32} & t_{33} \end{bmatrix} \begin{pmatrix} x_t \\ y_t \\ 1 \end{pmatrix}, \qquad (2)$$

where T is the Homography matrix, the transfer between 2 image. In order to compensate the camera motions, we extract feature points from the frame $C^{t}_{(x,y)}$ as explained by J. Shi *et al* [26]. Next, we use Kanade-Lucas-Tomashi (KLT) for tracking the features points in the next frame $C^{t+1}_{(x,y)}$. After that, we find a projective transformation matrix between the two frames which is called the homography matrix T by RANSAC method [27]. From matrix T, we compute the reference motion compensated image $C^{t+1'}_{(x,y)}$ as

$$C^{t+1'}_{(x,y)} = TC^{t}_{(x,y)}. \qquad (3)$$

We subtract $C^{t+1}_{(x,y)}$ from $C^{t+1'}_{(x,y)}$ to get the absolute different image $D^{t+1}_{(x,y)}$. The moving foreground objects are independent from the camera motion as follows.

$$D^{t+1}_{(x,y)} = \left| C^{t+1'}_{(x,y)} - C^{t+1}_{(x,y)} \right|. \qquad (4)$$

In an ideal case, the error image $D^{t+1}_{(x,y)}$ only contains the moving foreground objects. However, in reality, our experiments show that when the user walks, the camera motion changes even stronger than the object movements do. As a result, the error image also contains the false positive pixels. Using normal methods which are applied on a gray scale image to get the moving foreground objects is impossible in this case. Hence, we propose to use color information from the original image $I^{t}_{(x,y)}$. In this step, we adopt an adaptive color threshold on different color image $D^{t+1}_{(x,y)}$ to get the results on different images. The proposed error image is presented as the following equation.

$$E^{t}_{(x,y)} = \begin{cases} 0 \;\; if \;\; D^{t+1}_{(x,y)} = C^{t}_{(x,y)} \;\; or \;\; D^{t+1}_{(x,y)} < Threshold \\ I^{t}_{(x,y)} \qquad\qquad otherwise \end{cases}. \qquad (5)$$

We use the morphology technique to get the moving foreground objects. If the moving object is detected, the program will give a warning sound to the user via Head phone.

III. EXPERIMENTS

In order to make a small wearable device with high processing ability, low-power consumption, and light weight , We chose Raspberry Pi 2 model B (RPI) [28][29] as the main processing board due to low-power consumption, light weight, and high processing ability. In fact, the Raspberry Pi 2 model B works as a minicomputer, we can implement our algorithms on this model. In addition, Raspberry Pi 2 model B size is the credit size, so the users can easily put the processing board in their pockets. The small LCD with low power consumption is used for setting the system when it is activated. The camera module which we use to capture data from the outside environment is Raspberry Pi camera module. Raspberry Pi camera module has 5-

Megapixel photography, a high frame rate of 720p/60fps high-definition (HD) video capture, low noise, low crosstalk image capture. Additionally, the camera module is very small size element (25x20x9mm) and light weight (3 grams). These characteristics are suitable for researchers to create real devices for demonstrating the ability of the system. The view range of the system is base on the position of the camera when the users use our proposed system. In order to detect the moving objects and to avoid the obstacle in front of their view, they can put the camera eye on the forwarded view. In contrast, if they want to monitor the moving objects in their back, they can put the camera on their back size to make a back monitoring system. The final device hardware is presented in Figure 3.

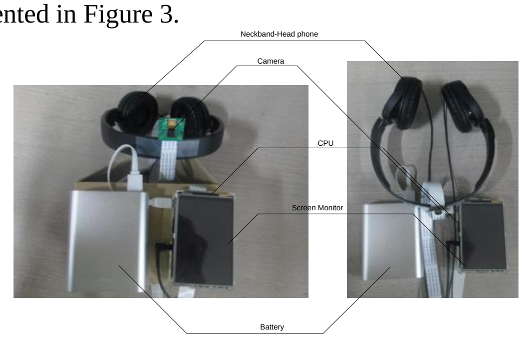

Fig. 3. The Proposed Wearable Devices (Example Figure)

In our experiment, we recorded videos in real life with difference user walking speeds in indoor and outdoor environments. The proposed software architecture is implemented by using OpenCV library and Python programming language, which is the default programming language for Raspberry Pi microprocessor.

IV. RESULTS

In this section, we provide the processing time of the system and the final results with illustrational images to clarify our work.

The processing time of each step is shown in Table II. Based on the time consumption, we can say that, the response of the system is really quick compared to a few seconds in the existing work. The time will surely assist the users in their reflex with their surrounding environments, especially outside.

Table II. Time Consumption of Each Step

Time consumption	
Step	**Time consumption(second)**
Pre-processing	0.0109
Camera motion compensation	0.2542
Color correction	0.1969
Total Time	**0.462**

We have tested our proposed methods to cancel the noise in different cases. We observed user walking movements on several video sequences with different walking speeds. The data is recorded in both indoor and outdoor environments. The results are presented in Table III. It is shown that, the accuracy increases as the users walk more slowly. It is obvious that the outside environments causes more noise that the inside ones that leads to the less accuracy.

Table III. Time Consumption of Each Step

Table Column Head			
Video Sequence	***Environments***	***Walking Speed***	***Accuracy***
Video 1	Indoor	Fast	72.61%
Video 2	Indoor	Normal	75.35%
Video 3	**Indoor**	**Slow**	**90.48 %**
Video 4	Outdoor	Slow	85.72%

All the working procedures are illustrated in Figure 4. It is the final detect results. The results follow the three steps of processing to cancel noise as mentioned Section II. Statistic noise is removed in Figure 4(c, f). The rest of the images are (g)(j)-Features detection results on 2 images, (h)-Normal subtraction results, (i)-Motion noise reduction between 2 images, (k)-Color threshold result, (l)-Final detection result, respectively.

V. CONCLUSION AND FUTURE WORK

In this paper, we proposed noise cancel methods utilizing microprocessors. Wearable electronic devices are implemented and also refined for monitoring purposes. The main goal is to assist disabilities when walking in both indoor and outdoor environments. Due to the effects of noise, this paper proposed two combined features of video sequences, motion features and color features to detect the moving objects. In comparison with other systems, the proposed system is cheaper and suitable for the single users. The propose method decreases the effect of noise of the outside environments. The proposed device works in real-time and high accuracy both in indoor and outdoor environments. In future work, we will continue improve the device to improve either the accuracy or the time consumption. The proposed system also can be used in the other applications such as monitoring the around environments of car, or surveillance purposes using drones and other mobile navigation applications.

ACKOWLEDGMENTS

This work is supported by Thai Nguyen University of Technology (TNUT), Thai Nguyen city, Vietnam.

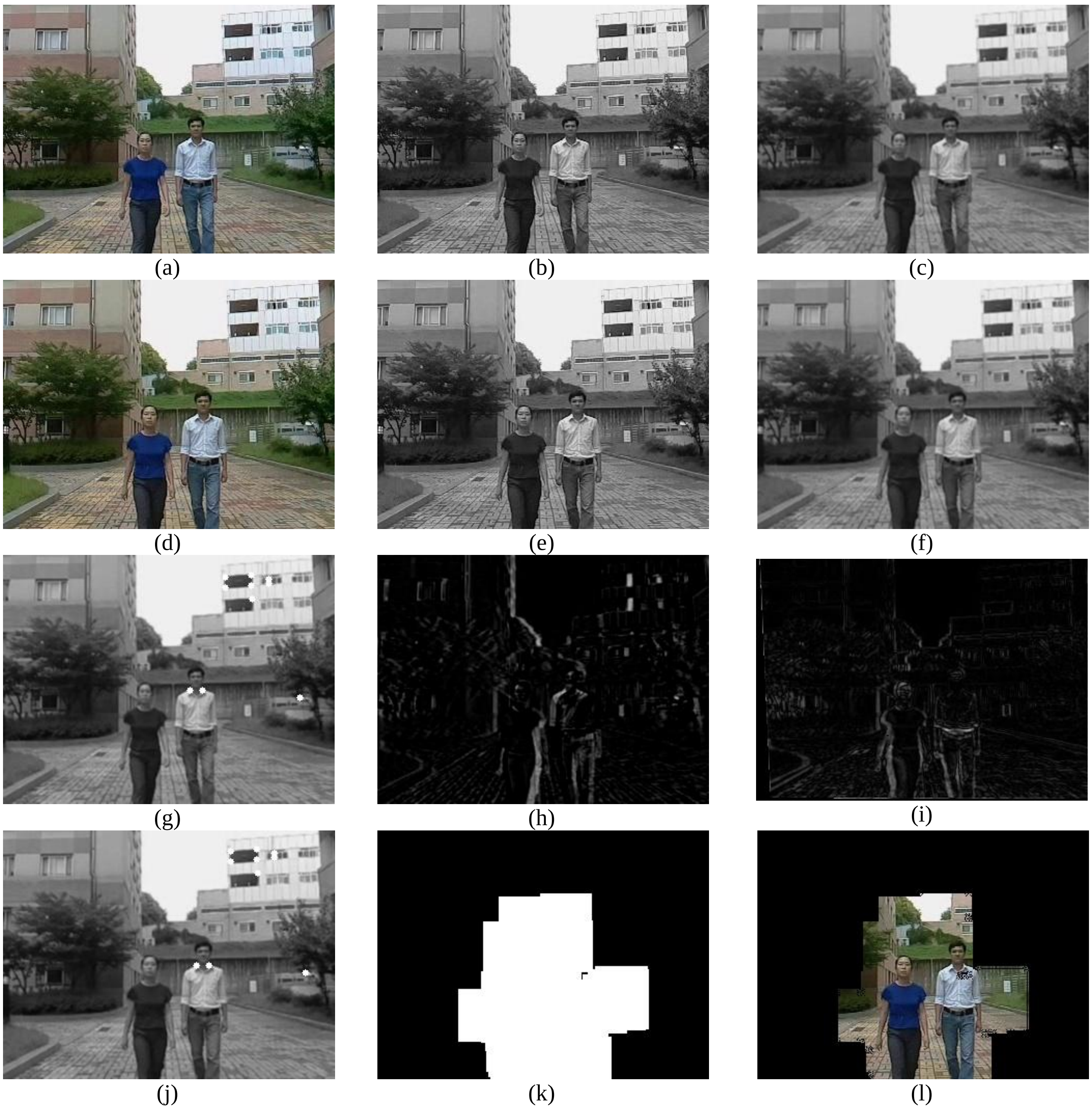

Fig. 4. (a)(d) Two Consecutive Images, (b)(e) Two Consecutive Grayscale Images, (c)(f) Two Statistical Noise Removed Images, (g)(j) Features Detection Results on 2 Images (h) Normal Subtraction Results, (i) Motion Noise Reduction Between 2 images, (k) Color Threshold Result, (l) Final Detection Result.

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