1. INTRODUCTION

In the United States, about 30% of adults above 65 years of age suffer a fall annually. There are many risk factors that can cause the elderly to fall, and they can be roughly classified into three categories: intrinsic factors, extrinsic factors, and exposure to risk. Researchers have worked for a long time to develop various kinds of fall prevention and fall detection systems. Therefore, a line-laser obstacle detection system that detects environmental obstacles to prevent falls in advance is provided in this paper. The system is installed on the toe end of shoes, and when the obstacles are recognized, the system will send alarm messages to catch the attention of the elders.

2. RELATED WORK

Popular range-based sensors include ultrasonic sensors, laser range finders, radar, and stereo-vision. Ultrasonic sensors are cheap but suffer from specular reflection problems. Laser range sensors have higher resolution, but they are more complex and more expensive than ultrasonic sensors. Stereo-vision is computationally expensive and difficult to be a practical solution. Engineers have developed methods and various kinds of systems for obstacle detection based on the above-mentioned range sensors-

1. a color stereo camera and a single axis radar for cross-country autonomous systems.

2. an approach for wall collision avoidance using a depth map based on optical flow from onboard camera images.

3. a method to classify road surface, traffic isle, and obstacle detection using rectangular digital elevation map from dense stereo data.

4. a novel algorithm for on-road obstacle detection based on stereo cameras.

5. developed an obstacle detection methodology, which combines two algorithms: adaptive color segmentation and stereo-based color homography. This algorithm is particularly suited for environments where the terrain is relatively flat and of roughly the same color.

6. designed an integrated triangulation laser scanner for obstacle detection installed on miniature mobile robots. The basic components of the triangular laser system are composed of a laser emitter and a camera; therefore, the system becomes smaller and has less power demand.

A camera-based line-laser technique that requires much less computation is proposed to detect obstacles. Because of its lesser computational amount, the extracted line-laser pattern has a high potential to be implemented on embedded systems. In addition, the simple components reduce the costs of the overall system. Therefore, complete integration of the system on shoes for the purpose of fall prevention can be achieved.

3. METHOD

In our system configuration, a line laser is mounted on the side of the shoes and an RGB camera is fixed but tilted down on the top side of the shoes. The relative position between the line laser and the camera is extremely rigid to deliver a consistent obstacle detection result. To have a good depth resolution, the distance between these two components should be as large as possible. Because the average step length of older people is around 0.808 m, the detection region of our system is 0.5–1.0 m.

In our prototype, a Logitech C310 webcam that operates at 29 frames per second under a 640 × 480 resolution and a 405 nm wavelength laser is used. Both of them are mounted rigidly to have consistent calibration parameters. Moreover, to suppress the noise interference, blue glass paper is used as a band-pass filter to resist the unnecessary light from the environment.

If the difference between two successive frames is very small, we assume that the users step on the ground. Besides, the moment the users raise the foot to the max height during a gait cycle also has the same effect. In both the above cases, the event for determining the obstacles will be triggered. Once the obstacle detection event is triggered, a series of line-laser pattern extraction steps will be executed. First, the median filter is applied in order to suppress noises. After that, a segmentation method is applied and Finally, the system will send alarm messages according to the dangerous levels of the obstacles classified by their widths and depths.

In our method, the normalized sum of absolute difference (SAD) value is utilized to compute the difference between two successive frames. In a gait, there are two phases: the stance phase and swing phase. Usually, the SAD value between frames during a stance phase should be very small. Similarly, the SAD value will be small when the feet are at the max height. Once the users start to move their feet forward, the SAD value will become very large in contrast to the stance phase. In our experiment, the relatively small SAD value happens in the middle and at the end of every swing phase. Therefore, the obstacle detection will be triggered when the SAD value is small.

Once the obstacle detection event is triggered, a median filter is then applied to suppress the bad influences coming from the environmental noise. After applying the median filter, an intensity threshold is set to separate the line-laser pattern from the background. At this step, any pixel with an intensity below the threshold is recognized as background or noise. On the other hand, if the intensity of a pixel exceeds the intensity threshold, it will be considered as a candidate pixel on the obstacles. After the extraction of the line-laser pattern, the extracted data are stored and processed again for obstacle clustering. The goal of this system is to recognize how far and how large the potential obstacles are. Therefore, a segmentation algorithm is needed after executing the line-laser pattern extraction procedure. This algorithm classifies each pixel on the line-laser pattern into several clusters that are likely denoting the obstacles. After executing the line laser pattern clustering, the physical distance is needed to be determined by homography transformation.

As long as the width and the depth of each obstacle can be calculated, the obstacle alarm level of each obstacle can be classified. Since the size and distance may affect the dangerous level, we use a coverage angle θ as a normalized factor for alarm. The system distinguishes the obstacles into four alarm levels. Alarm level 1 means the obstacle is the most dangerous, causing the system to send the most urgent and loud alarm messages. On the other hand, when the alarm level of the obstacles becomes 2 or 3, the alarm message will become weaker. Last, if the alarm level of the obstacles is 4, the system will not react and send any alarm messages.