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Development of Computer Vision based Windshield Wiper Control System for Automobiles

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Abstract – Windshield wipers play a key role in assuring safety and comfort to the driver in the adverse weather conditions. For various automotive applications, it is necessary to recognize adverse weather conditions like fog, rain, snow etc. as it is measure cause for accidents. Among all these raindrop detections is a quite challenging task.

This paper discusses the present wiper control system based on Computer Vision. The system is implemented on Embedded Linux platform with Computer Vision based raindrop detection using OpenCV library in Python. The system is designed using Embedded Linux development board. In this system, a camera captures images of the windshield of automobiles. The information of captured scene is processed using OpenCV. Raindrop detection is achieved by various techniques of the computer vision and image processing. The information of raindrop distribution is further used for wiper control. According to the percentage of occupation of raindrops, PWM is selected to control the motor.

Key Words*: *Raindrop Detection, Windshield, Advanced Driver Assistance System (ADAS), Computer Vision, Raspberry Pi (RPi).

1. INTRODUCTION

A close relation exists between weather recognition and driver's safety. Driving is difficult during the adverse weather conditions than the fair conditions, rates of accidents are comparatively high due to adverse weather. Many computer vision algorithms have been developed to work In-door and out-door applications. Many algorithms tend to fail in adverse weather conditions. So, changes in the climatic conditions can be recognized using in-vehicle vision sensor with some Computer Vision based algorithms. Nowadays, the number of sensors used for Advanced Driver Assistance Systems are increasing, especially in-vehicle camera systems are developed since images captured from these sensors contain almost all visual information. Auto-wiping systems are already developed with the help of rain sensing plate. But the employment of separate sensor for the various task is not desirable from the viewpoint of space, appearance, cost, maintenance etc. The single vision sensor employed in the vehicle can be used for many vision-based applications like distance adjustment between cars from leading vehicle recognition, self-steering from white line recognition, automatic braking systems from pedestrian recognition and so on.

These systems detect raindrops on the windshield and automatically turn on and adjust the wiper system in accordance with the intensity of the rain. If the driver takes their attention off the road for few seconds to adjust the wiper switch while driving in poor weather conditions would lead to road accidents. Such system is developed to reduce driving distractions and allow drivers to focus on driving.

1.1 Various Raindrops Detecting Sensors

In past years different approaches were used to control the wiper blades [10]. Some of them are described below:

1. Audio sensor: The condition of rain can be detected using microphone by listening to sound created by falling raindrops on a metallic panel such as a roof of the vehicle. This will require the use of a frequency selective filter to eliminate ambient noises.
2. Capacitive sensor: A film of capacitive sensors are embedded within the laminated layer of the front windscreen. The sensor detects an intensity of rain based on a fluctuation of the capacitive signals and resistance due to a connection of electrodes of the sensor via rain-drops. The manufacturing process is a limitation for this system, as many car windshields are not laminated, plus electrodes of the sensors require electric connections, which is difficult and costly. Once the sensing electrodes are wet, they become less sensitive for rain sensing.
3. Optical rain sensor: It is built on the theory of reflection of light. Infrared light is projected on the windshield from source, which is collected by a photo detector and based on the change in the amount of reflection of light, the system

recognizes the presence of raindrop in the windshield and moves wiper automatically. Unwanted objects like darts and leaves lying on the windshield can easily disrupt the reflection path of light. Besides, the sensor becomes sensitive to external lights As IR lights are used, the sensor suffers from small sensing area.

4. Omni-directional rain sensor: These sensors are similar to optical rain sensor but instead of throwing light at a certain angle like previous methods, light is scattered in all directions. The photodiode receives scattered light reflected by the raindrop and calculates the intensity of received light. The approach is helpful to cover big surface areas. But still not efficient in case of differentiating other particles from raindrops.
5. Image sensor: Image processing approaches were used to detect raindrops using image sensors.

1.2 Image processing techniques for raindrop detection

Various image processing approaches were used to detect raindrops using vision sensors. Intensity variation & Contour verifications in [4], Time-series in [3], Improved RIGSEC in [7], pattern matching in [2] are some of the approaches used for raindrops detection.

1.3 General system for raindrop detection using Computer Vision

Image processing based approach for the detection of raindrops covers the maximum area of windshield depending on the field of view of the camera. The vision-based system can give real time and more accurate raindrop detection. General system using the camera for raindrops detection is as shown in Fig.-1. It can be explained in the following steps

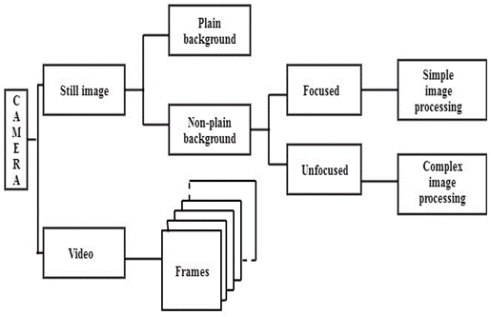

Fig-1: General system for raindrop detection using Computer Vision

- The camera will capture a continuous stream of images or video frames. Processing of images, as well as frames for detection of raindrops, is possible.
- Detection of raindrops from images with a plain background is the most effective detection. But it may fail for the heavy rainfall.
- For detection, over a non-plain background, the camera can be focused on the windshield. It can be called as focused raindrop detection. With simple image processing, it is possible to detect raindrops.
- If the background is non-plain and the camera is not focused on the windshield then detection of raindrops will be time-consuming as complex image processing techniques like pattern recognition and pattern matching, spatiotemporal correlation analysis of video sequence, watershed algorithms will be implemented.

Simple Computer Vision techniques will consume less time and process the focused images. Unfocused raindrop detection will be time-consuming than the focused raindrop detection.

2. WIPER CONTROL SYSTEM IMPLEMENTED IN OUR PROJECT

The system we have implemented is based on Embedded Linux board called Raspberry Pi 3 Model B having OpenCV library installed on it with the necessary software. The Raspberry Pi camera module is interfaced with the board captures continues images. With the image processing techniques raindrops are detected and thus the percentage of accumulation is calculated. According to that duty cycle of PWM output of RPi GPIO is controlled and thus speed of wiper motor. The whole system is the composition of the following:

A. CAMERA

The RPi camera module version v1 with 5-megapixel resolution is having a frame rate of 30 for the mode 1080 video mode. The sensor is OmniVision OV5647. Sensor resolution of 2592x1944 pixels and sensor image area is 3.76mm x2.74mm pixels. The horizontal field of view is $53.50+/- 0.13^0$, vertical field of view is 41.41^0 and diagonal is 66^0. So, the focus is adjusted at about 10 cm, by moving lens 126^0 counter clockwise.

Fig-2: Raspberry Pi camera Rev 1.3 is used in proposed system

B. Embedded Linux

The number of operating systems available to use on Raspberry Pi platform is having lots of options. For our project, we have used Raspbian Jessie on Raspberry Pi. The Raspbian operating system is based on Debian Linux. Embedded Linux is more beneficial as it is open source, stable, scalable, reliable, with all kind of hardware support and has great community support. OpenCV3.0 library in Python 2.7 is used for programming.

C. Raspberry Pi 3 Model B

The Raspberry Pi is a credit card-sized single-board computer developed in the UK by the Raspberry Pi Foundation. The role of Raspberry Pi in this system is processing images captured by the Raspberry Pi camera using OpenCV library. This newest version is available with 1 GB RAM, 1.2 GHz frequency which will give us fast computation.

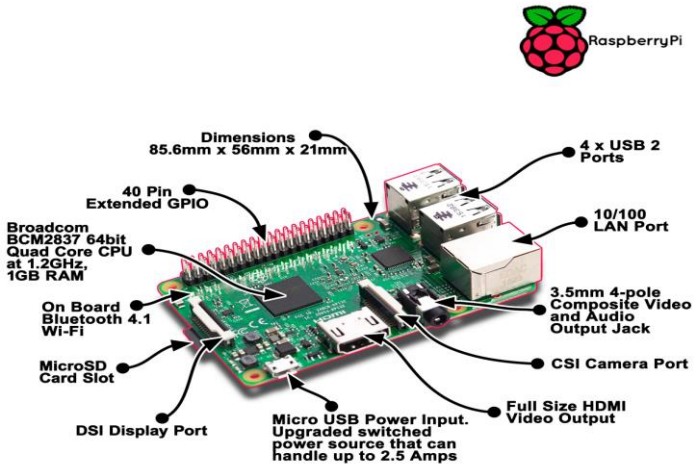

Fig-3: Raspberry Pi 3 Model B

D. HARDWARE REQUIREMENT

Hardware required in the proposed system will be a combination of the all above. A general block diagram of component connectivity is as shown in Fig-4. Below

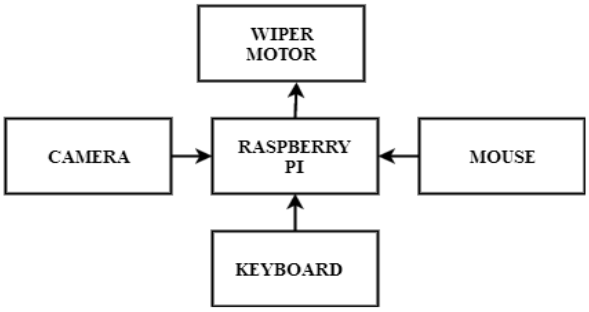

Fig-4: Proposed system

3. CHALLENGES IN THE RAINDROPS DETECTION

Advanced driver assistance systems include a camera for vision-based automation. The geometry of raindrop varies depending upon the type of rain, wind direction, car speed, vibrations etc. Focused raindrops detection algorithms are less time-consuming. In rainy days each and every pixel exhibit sudden changes in the intensity. This changes may be caused by other factors like external illumination changes, camera movement etc.

During heavy rain, the raindrops stay for a short time on the shield (maximum of 500 milliseconds)[6]. Different properties of rain, wind speed, and lighting conditions are the major challenges in raindrops detection. Raindrop detection is the most challenging task as they are transparent on the windshield. Some of the challenges in the raindrops detection are listed below.

1. Complex Background

On the complex background, it is difficult to detect them as brightness variation may make an algorithm to fail. Generally, the brightness of raindrops is greater than the background, hence it can be easily detected with some image processing techniques.

2. Variation in ambient light

This can cause glare in the captured images which will make it difficult to detect raindrops on the windshield.

3. Camera mounting/vibration

To locate camera at best location inside windshield to capture images is one more challenge. Vibrations of the car will cause movement of the camera, so captured images might be blurred. Algorithm for blurred raindrop detection in necessary for that.

4. SOFTWARE IMPLEMENTATION

In literature survey, we found lots of work on raindrops detection using different methods. Our system will work on the focused raindrop detection and wiper control.

Raindrops detection is important to get a clear sight for driving in adverse weather conditions. In our system, while performing experiment we have initialized the camera, which captures continuous images with a frame rate of 20 frames per second. The images are provided to the Embedded Linux board i.e. Raspberry Pi which performs computer vision processing to detect raindrops from the captured images. The raindrops are having greater intensity than the background and this phenomenon is used here. The algorithm is implemented only for the day time raindrop detection as shown in fig.-4 below.

This system consists of three stages

4.1 Camera Initialization

In the first stage, the system gets initialized with the onboard Pi camera. The camera captures continuous frames and sends to the Raspberry Pi for further processing. The camera module is enabled through **sudo raspi-config** command on RPi.

Commands used to test the Pi camera are

sudo raspistill –o image.jpg for capturing still image with name image
sudo raspivid –o video.h264 for capturing video with name video

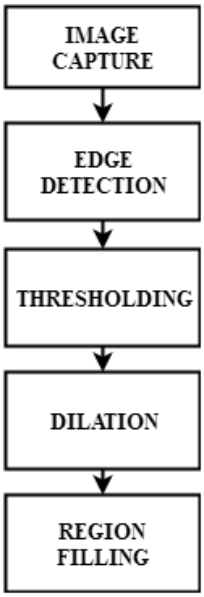

Fig.-5: Flowchart for raindrop detection

4.2 Computer Vision For Raindrop Detection

- First thing while processing the images in Computer Vision is that the image should be converted into greyscale. After this conversion Sobel operator is used for edge detection. Edge detection is a fundamental tool in image processing, machine vision, and computer vision, particularly in the areas of feature detection and feature extraction. Combined edge detected image is as shown in the fig.-6 below.
- On the trial and error basis threshold value of 100 is set to get the binary image for further processing. Binary image obtained is as in fig.-7.
- This further performed with dilation operation to decide the boundaries as shown in fig.-8.
- After dilation with floodfill command in OpenCV detected region is filled as in

  fig.-9.

Fig.-6: Sobel edge detection

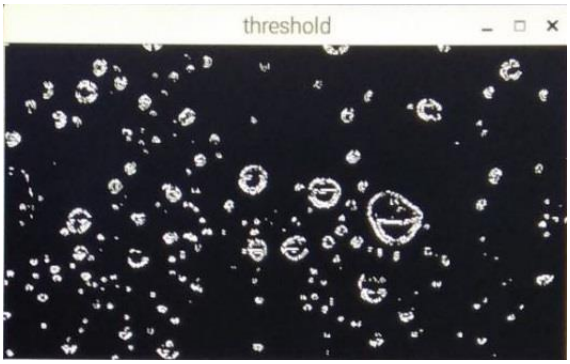

Fig.-7: Binary image

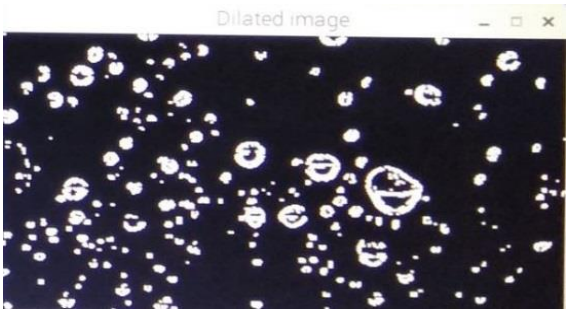

Fig.-8: Dilated image

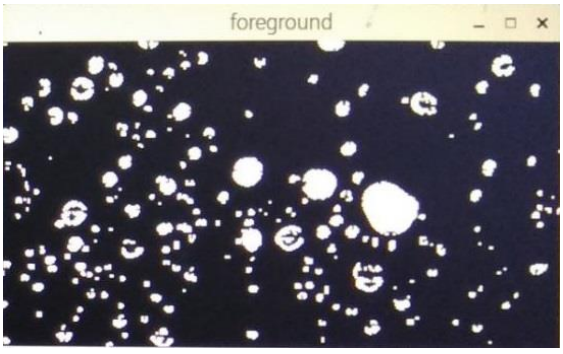

Fig.-9: Detected raindrops

- To count the detected raindrops and raindrops distribution blob detection and non-zero pixel count are performed respectively. Fig.-10 shows detected raindrops for the minimum area of 20 pixels.

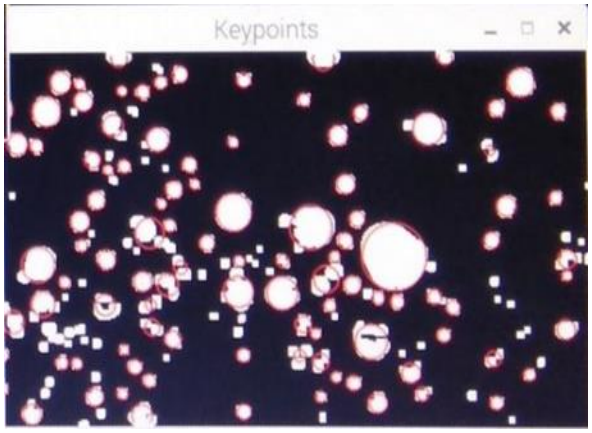

Fig.-10: Keypoints detected for counting raindrops

4.3 Wiper Motor Control

- For this Raspberry Pi's GPIO pins are accessed. Depending on the raindrops count and percentage of distribution calculated in image processing stage motor speed and an interval is controlled.
- For 0 raindrop count and 0 % distribution motor speed and interval both are zero.
- For 50 to 500 raindrop count medium speed and for 10 % to 50 % distribution medium interval is set for a motor.
- For 500 to 1000 raindrops high speed and for 50% to 100% high the interval is set for a motor.

The overall component connectivity is as shown in fig.-11.

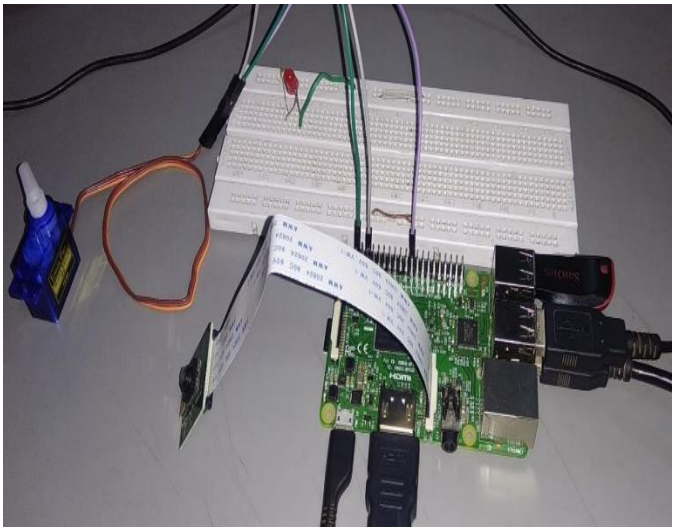

Fig.-10: Component connectivity

5. RESULTS

Detection of focused raindrops with proposed algorithm is as in the Fig.-12 below.

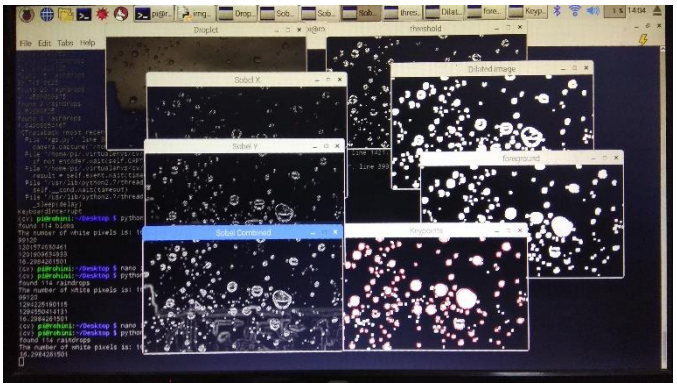

Fig.-12: Raindrop detection for the captured image

A number of raindrops detected is decided by the detector by checking the size parameter of a raindrop in pixels. Then according to the number of raindrops and percentage of distribution on windshield motor can be controlled.

6. CONCLUSION AND FUTURE SCOPE

In this paper, we represented general methodology, challenges, and implementation of our system. Detection of focused raindrops is promising as per this approach with some basic image processing algorithms. The results of raindrops detection can be used for judgment of rainfall, adverse weather recognition as well as for driver assistance. Windshield wiper controlling can be performed using the results of raindrops detection. The interface between OpenCV and Raspberry Pi GPIOs is very strong; so embedded hardware can be controlled by image processing programs written using OpenCV in Python.

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