Raindrop Detection: Performance analysis of recent approaches for the use in electronic driver assistance systems

[1]Saba N. Karbhari, [1]Prof. B.H. Pansambal
[1]ME Student, [2]Asst. Professor, [1,2]E&TC Dept. TSSM's Bhivrabai Sawant College of Engg. & Research, Maharashtra, India.
[1]sabakarbahri@gmail.com, [2]bpansambal@gmail.com

Abstract - **Advanced driver assistive system (ADAS) forms one of the most important as well as a common feature in today's automotive industry. ADAS depends upon various sensors that aid the driver in visual or auditory feedback. Video based driver assistive systems are designed to work in clear weather and often fail to be of any help in rainy climatic conditions. This affects the overall performance of ADAS. Various research studies make use of algorithms and photometric models of raindrop for its detection and provide a reliable feedback signal. This paper reviews various techniques and photometric models defined for raindrop detection in various climatic conditions.**

Keywords —Driver assistance, photometric model, raindrop detection, watershed

I. INTRODUCTION

Recently there has been a commendable research work on advanced driver assistance systems (ADAS). Visual aid has proved to be of great help for the driver assistance. In-vehicle cameras capture the rapidly changing traffic environments and are used in various driver assistance systems that use video images viz. distance adjustment, Automatic braking systems, self-steering using white line recognition[11]. Likewise, the in-vehicle camera is useful to record the change in climatic conditions. The driving conditions worsen as the climate changes from clear to rainy/storm conditions. Video images obtained from the in-vehicle camera thus can be used to detect bad weather conditions in real time domain and provide speed control as well as benefit ABS system using this information. The rain condition can be directly identified by measuring the drops that are captured by this camera. Depending upon the nature of the rain, the raindrop pattern hitting the windscreen changes and provides a fair idea of the climatic conditions. The raindrop geometry varies depending upon various rain types, wind direction, car speed etc. This often makes the electronic system incompetent to provide accurate data about the raindrops hitting the screen. To overcome this drawback and improve the performance of ADAS various photometric models have been studied and implemented as well as background subtraction and watershed algorithm are used. Detected results comprise of true positives and false positives, where FP often is some noise and not the actual raindrop. Various algorithms developed work on reducing the false positive detections.

The In heavy rain the raindrops stays for a short duration (maximum of 500 milisec) [7]. Often these raindrops are unfocused and detecting them accurately is a big challenge for the electronic systems. A system for detecting unfocused raindrops without modifying the camera distinctiveness was developed [1]-[7]. Statistical learning methods as well as image processing algorithms are used to detect the raindrops on car windscreen that can be further used by ADAS systems. Wherein Photometric models were used to detect stationary spherical raindrops and streaks [2]-[8]. Spatiotemporal method approach proposed by Nashashibi et al.[7] requires flexibility & improvement. Martin Roser and Frank Moosmann presented a study to discern several types' rainy conditions but their approach cannot localize raindrops within image [4]. Kshitiz Garg and Shree K. Nayar developed correlation model based on comprehensive analysis based on dynamics & photometric properties of raindrops but their algorithm cannot handle steady effect of rain also cannot remove defocused rain streaks [9].M. Roser and A. Geiger proposed photometric model in which they detected raindrops on a single images using photometric properties of raindrops. But their model does not cover all shapes of raindrops [2].Using template matching H. Kurihata, T. Takahashi, I. Ide, Y. Mekada, H. Murase, Y. Tamatsu, and T.Miyahara obtained a good result to detect raindrops on car windshield from video sequence [1].Cord & Aubert detected focused raindrops using pattern recognition technique [3]. Machine learning approach with

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raindrop templates, so called Eigen drops was used to detect raindrops on windshields [1]. Results within the sky area were promising, whereas the proposed method produced a large number of false positives within the non-sky regions of the image where raindrop appearance modelling becomes more challenging. This paper reviews and compares various techniques for raindrop detection to provide a reliable feedback for ADAS using front view in-vehicle camera in a car [10].

TABLE I.
WEATHER CONDITION AND ASSOCIATED PARTICLE TYPES

Condition	Particle Type	Radius (μm)
Haze	Aerosol	10^{-2}
Fog	Water Droplet	1-10
Cloud	Water Droplet	1-10
Rain	Water Drop	10^{2}-10^{4}

II. Methods

A. Raindrop Detection

Driver assistive systems shows limited functionality when it comes to bad weather conditions, especially when an assistance and guidance in such climatic conditions is mostly required. A reliable raindrop detection system can provide proper compensation for the shortcomings of today's vision sensors in rainy weather by providing additional information like raindrop position and size.

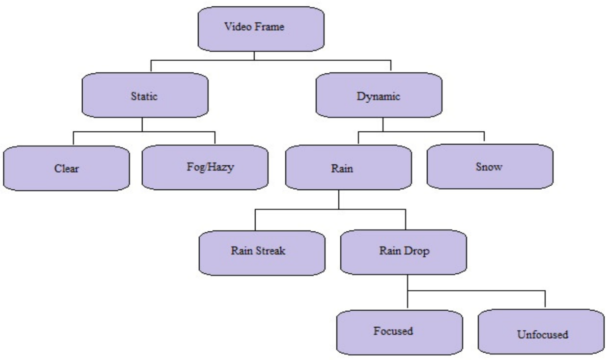


Fig. 1 Weather Classification

These parameters can then be used to enhance image processing algorithms for ADAS and are an important step towards extending their functionality to adverse weather conditions [raindrop]. Bad weather conditions can be classified into two main categories: Static or steady weather conditions such as fog, mist, or haze and dynamic weather conditions such as rain, hail, or snow. Whereas many attempts have been made at resolving static weather problems like fog or haze [8], [11], [12], [13] research in machine vision for dynamic weather conditions is sparse.

a. Image b. Raindrop Detection
Fig. 2 Detection under static conditions, S. You et.al

B. Raindrop Modeling

Geometric properties of the raindrop are useful in predicting a presence of raindrop in an image. Raindrops hitting the car windscreen exhibit various geometrical shapes depending upon speed of rain, wind, car and also the nature of the windscreen glass. Even if the raindrop loses its focused form, the unfocused raindrop partially shows the similar light refraction model. Various models use the follow approaches.

1. Spatial Derivative of focused Raindrop
2. Temporal Derivative of unfocused raindrop

Various photometric models have been developed and tested for raindrop detection. Fig. 3 shows the raindrop detection results [1][2][3]. The false positive values are more in the last image.

a. Image b. Kurihata et.al c.Roser et.al
Fig 3. Raindrop Detection. Dynamic background

C. Detection Algorithm

For detecting the raindrop, following flow is observed based on the following characteristics of raindrop:

1. A raindrop usually appears on an image with spherical form.
2. The illumination of a raindrop is higher than its surrounding area.
3. Raindrop shape is closing similar to an ellipse.
4. When a raindrop is obvious, the change of the gradient around the boundary is more apparent.

Table II reviews the method used for raindrop detection model.

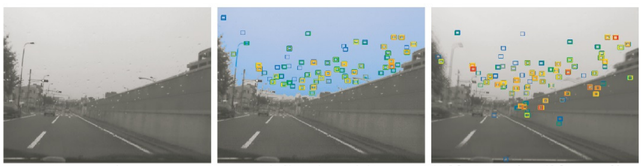
Table II: Existing Raindrop detection model

Author	Detection Algorithm	Year	Type
Qi Wu et.	Visual Salient Features	2012	Focus
Sugimoto et. al	Improved RIGSEC	2012	Focus
Roser et. al	Bezier Curves	2011	Focus
Nomoto et. al	Epipolar Geometry	2011	Focus
Ching-Lin Yang [	Intersection operation	2011	Focus
Nashashibi et. al.	Intensity variation & Contour verifications	2010	Unfocused
Schwarxlmuller et. al	Support Vector Machine	2010	Focus
Roser & Geiger	Improved RIGSEC	2009	Focus
Halimeh & Roser	RIGSEC	2009	Focus
Yamashita et. al.	Template matching	2008	Focus
Miyahara et. al	Principle Component Analysis (Eigen drops)	2007	Focus
Kurihata et. al	Time-series	2007	Focus

Fig. 4 shows the detection results using BLUR and combination BLUR+RIGSEC method. The latter is more reliable in terms of predicting the raindrop at dynamic conditions.

a. BLUR b. RIGSEC+BLUR
Fig. 4 Detection using BLUR and combination BLUR+RIGSEC. Red marks show False Positives.

Though the combinational result is accurate, the sphere section assumption of the above model does not cover all raindrop shapes which is a major disadvantage for heavy stratiform rainfall. Also making use of temporal dependencies in raindrop location and appearance can improve the overall detection rates.



a. Raindrop detection using Time Series method. b. Sky region restriction c.5 frame averaging+10-frame matching H.Kurihata et.al.

The detection rate of above method are excellent for a light rainfall. The precision improved as the number of frames processed using the algorithm increased.

III. Conclusion

Raindrop detection techniques can provide a wider and efficient operation for driver assistive systems. Raindrop detection in bad weather conditions can be used for automatic speed control in ADAS. Due to different properties of rain, wind speed and light conditions, detection of the raindrops on the windscreen accurately has become a complex job for researchers. Photometric models as well as various detection algorithms provide some advantages as well as disadvantages which has resulted in no concrete solution to be used in bad weather conditions. Out of the above studied methods, the method proposed by H. Kurihata, which uses time series averaging provided efficient detection with least false positives. The intensity based correlation method proposed by M. Roser et.al provides acceptable results but has a high computational time. Method developed by S. You et.al using the temporal intensity change of the drop is very efficient in static or slow changing environments. Thus for ADAS, methods proposed by H. Kurihata suits best for low stratifrom rain or drizzle. For heavy rain conditions, where streaks are dominant, ADAS may still have to wait for some more time as more research is done for focused as well as unfocused raindrops.

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