Adherent Raindrops Detection and Removal in Video

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Adherent Raindrops in Video

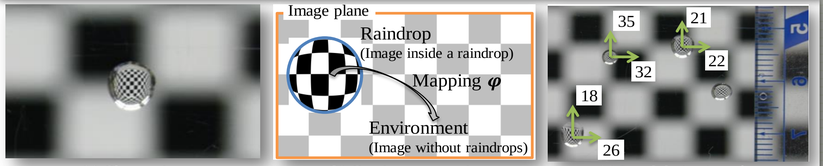
In a rainy day, it is inevitable that raindrops will appear on the windscreen, camera lens, or the protecting shield, causing the vision systems to be affected by the raindrops. The effect is particularly problematic when the vision systems use a hand-held camera or a top-mounted vehicle sensor where no windshield wipers can be used.

Challenges in Detecting Adherent Raindrops

Various shapes Transparency Blurring Glare

Identifying adherent raindrops from images can be problematic due to a few reasons: Foremost, adherent raindrops have various shapes. Unlike opaque objects, they are transparent, making their appearance and thus intensity values vary depending on the environment. They suffer from out-of-focus blur due to their proximity to the camera. Moreover, most raindrops generate glare.

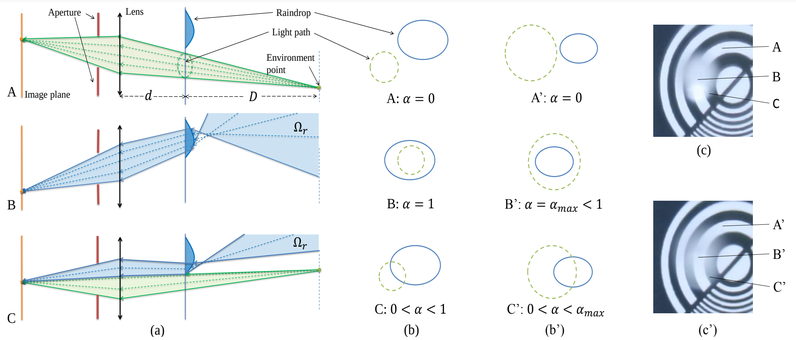
Modeling of Clear Raindrop



(a) Observation (b) Continuous mapping (c) Local derivative of φ

(a) A raindrop is a contracted image of the environment. (b) On the image plane, there is a smooth mapping φ' starting from the raindrop into the environment. (c) The contraction ratios from the environment to a raindrop are significant.

Modeling of Blurred Raindrop



(a) (b) (b') (c) (c')

The appearance and model of pixels on an image plane collecting light from A: environment, B: raindrop, C: both. (a) The light path model. Green light: the light coming from environment point; Blue light: the light refracted by a raindrop. (b) The raindrop plane cut the section of model in (a) when a raindrop is big. Green circle: the area of light collected. Blue circle: the raindrop. α: percentage of light collected from the raindrop. (b') A raindrop plane cut the section when it is small. (c) The appearance of the 3 situations in (b). (c') The appearance of the 3 situations in (b').

Methodology

(a) Image sequence (b) Inter frame SIFT flow (c) Summation of (b) over 100 frames

A clear, unblurred adherent raindrop works like a fish-eye lens and significantly contracts the image of a scene. Consequently, the motion inside raindrops is distinctively slower than the motion of non-raindrops.

(a) Image sequence (b) Inter frame intensity change (c) Summation of (b) over 100 frames

Unlike clear raindrops, blurred raindrops are mixtures of rays originated from the points in the entire scene. Thus, the intensity temporal derivative of blurred raindrops is significantly smaller than that of non-raindrops.

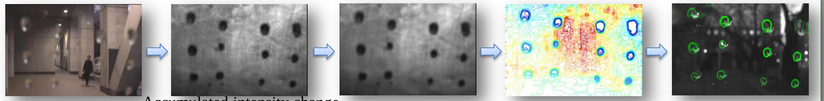
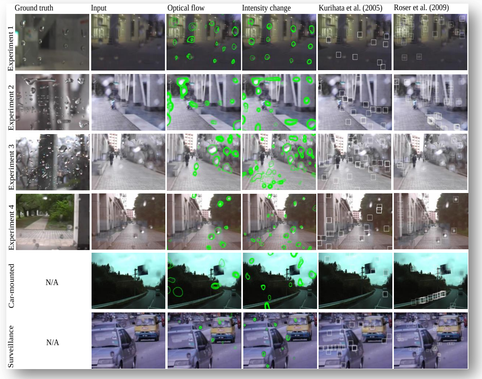
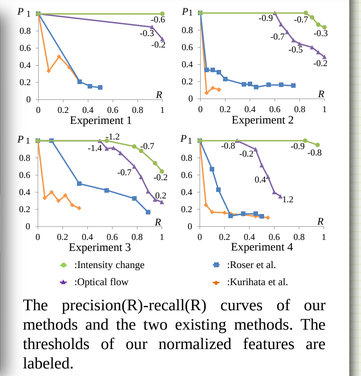


Image sequence → Accumulated intensity change or optical flow → Reduce noise → Level set → Refined detection

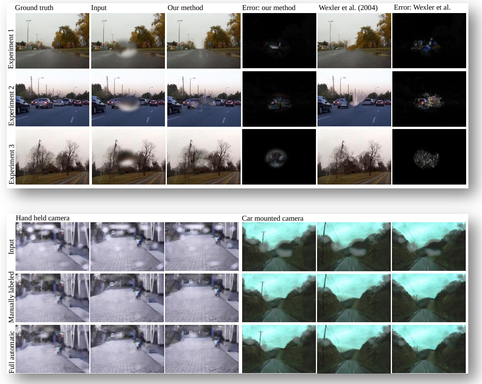
Detection

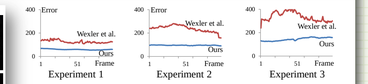




The precision(R)-recall(R) curves of our methods and the two existing methods. The thresholds of our normalized features are labeled.

Removal





Upper left: The raindrop removal results using our methods and the method of Wexler et al.

Upper right: The average (R; G; B; dx; dy; dt) error on recovering 100 continuous frames of the left experiments.

Lower left: The raindrop removal using the our method. First row: the input sequence. Second row: the removal result with the raindrops manually labeled. Third row: the removal result with the raindrops automatically detected.

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