論 文 の 内 容 の 要 旨

論文題目　Detection and Removal of Raindrop Images in A Video Sequence and Their Applications to Computer Vision Algorithms

（ビデオシークエンス中の付着雨滴像の検出、除去並びにそれのコンピュータビジョンアルゴリズムへの応用）

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Raindrops appeared on windscreens or window glass can degrade the visibility of the outside scenes. If we can detect and later remove the raindrops, many applications such as intelligent vehicle system will benefit from it.

In this thesis, we intend to focus on developing methods of automatic raindrop detection and removal. And we utilizes raindrop to perform a few image processing tasks. To achieve these goals, we have theoretically analyzed the imaging system with the presence of water drops. Based on our analysis, we have developed three automatic raindrop detection and removal systems. Furthermore, with the insights on properties of water drops, we developed an single image stereo system using water drops.

The first system utilizes the assumption of the smooth motion of camera/scene. The idea is to use long range trajectories to discover the motion and appearance features of raindrops locally along the trajectories. These motion and appearance features are obtained through our analysis of the trajectory behavior when encountering raindrops. These features are then transformed into a labeling problem, which the cost function can be optimized efficiently. Having detected raindrops, the removal is achieved by utilizing patches indicated, enabling the

motion consistency to be preserved. Our trajectory based video completion method not only removes the raindrops but also complete the motion field, which benefits motion estimation algorithms to possibly work in rainy scenes. Experimental results on real videos show the effectiveness of the proposed method.

The second system is also based on the smooth motion which is a fast and robust method. In comparing with the first method, this method aims to speed up the video restoration by replacing the dense motion estimation with sparse motion and interpolation. In the situations that the motion is smooth and stable, the restoration quality is comparable with the first method. It is principally based on sparse matching and interpolation. First, SIFT, which is robust to arbitrary motion, is used to efficiently obtain sparse correspondences in neighboring frames. To ensure these correspondences are uniformly distributed across the image, a fast dense point sampling method is applied. Then, a dense motion field is generated by interpolating the correspondences. An efficient weighted explicit polynomial fitting method is proposed to achieve spatially and temporally coherent interpolation. In the experiment, quantitative measurements were conducted to show the robustness and effectiveness of the proposed method.

The third system is based on the contraction properties of water drops. The core idea is to exploit the local spatio-temporal derivatives of raindrops. First, we explicitly model adherent raindrops using law of physics, and then, detect them based on these models in combination with motion and intensity temporal derivatives of the input video. Second, relying on an analysis that some areas of a raindrop completely occlude the scene, yet the remaining areas occlude only partially, we remove the two types of areas separately. For partially occluding areas, we restore them by retrieving as much as possible information of the scene, namely, by solving a blending function on the detected partially occluding areas using the temporal intensity derivative. For completely occluding areas, we recover them by using a video completion technique. Experimental results using various real videos show the effectiveness of the proposed method.

Based on the experience on detecting and removing rain drops, we find that water drops are not always noise in image/video but can be used to perform a variety of vision tasks. Therefore, we propose a novel single image stereo system, which utilizes a common camera with a few water drops. The key idea is that a single water drop adhered to window glass is totally transparent and convex, and thus can be considered as a fisheye lens. If we have more than one water drop in a single image, then through each of them we can see the environment with different viewpoints, similar to stereo. To accomplish this idea, foremost, we need to rectify every water drop imagery to make distorted planar surfaces look flat. For this, we consider two physical properties of water drops: (1) a static water drop has constant volume, and its geometric convex shape is determined by the balance between the tension force and gravity. In other words, the geometric shape can be obtained by minimizing the overall potential energy, which is the sum of the tension energy and the gravitational potential energy. (2) The imagery inside a water-drop is determined by water-drop geometric shape and total reflection at the boundary. This total reflection generates a dark band commonly observable in any adherent water drops. Once the geometry of water drops recovered, we rectify the drop images through ray-tracing. Based on a set of the rectified images of water drops, we can compute depth using the concept of stereo. In addition, we can also refocus the whole input image. Experiments on real images and a quantitative evaluation show the effectiveness of our proposed method. To our best knowledge, never before have adherent water drops been used to estimate depth.