論 文 の 内 容 の 要 旨

論文題目
Fast Image Layer Separation by Exploiting Correlation among Multiple Features
（複数特徴間の相関を活用した高速画像レイヤ分離）

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Image layer separation for decoupling an input image into different component layers is a challenging task in computer vision and has many practical applications. It is inherently an ill-posed problem and cannot be solved without additional information and assumptions. Two types of image layer separation problems are studied in this dissertation: intrinsic image decomposition and structure texture separation, and they were found to be closely related to each other. A particular focus is placed on robustness and the computational efficiency of layer separation as they are important for applications to many problem domains such as virtual reality and gaming. To this end, the correlation between different kinds of features extracted from a given image was exploited to alleviate the ill-posedness of the problem of layer separation. The image formation in the two different layer separation problems was individually analyzed and the useful and robust correlation of features was exploited. Those features, though exist in all the layers of an input image, have different statistical properties and contain different level of information that specify the intrinsic characteristics of the layers.

The main content of this dissertation is divided into three parts. The first part of this thesis proposes a fast method of intrinsic image decomposition based on a single image. Single image-based intrinsic image decomposition is a critical problem since it facilitates many applications in low-level and high-level computer vision domain, as well as those in computer graphics domain. Those applications normally require the understanding of objects' materials, objects' textures and even environmental lighting and the property of the scene where objects are located, which is highly related to the purpose of intrinsic image

decomposition. However, single image-based intrinsic image decomposition simultaneously involves a difficult problem with intrinsically existing ill-posedness, which comes from that the solution space has higher dimension than the dimension of input constraints. Therefore, it worths researchers' concerns on proposing effective methods to make it solvable. Previous work has proposed different kinds of prior knowledge or additional information such as user interaction or knowledge learnt from related data to render this problem easier to solve. A novel edge-based method of intrinsic image decomposition was proposed in this chapter by exploring the correlation between a chromaticity gradient map and an albedo gradient map to exploit another kind of prior knowledge based on color information. This ill-posed problem was specifically addressed in the use of a single image and exploited the use of the chromaticity gradient map to guide recovery of the albedo gradient map; The Retinex assumption was also regularized by using the ℓ_0-norm to piece-wise flatten the albedo layer. The proposed method is simple yet computationally efficient. Experiments were carried out to evaluate the method both qualitatively and quantitatively on public datasets. The experimental results indicated that our method ran much faster than state-of-the-art methods while achieving comparable performance.

The second part of this dissertation addresses the problem of structure-texture separation, which is another common existing layer separation problem. For some applications, structure-texture separation, especially the output structure layer of separation, can be an important preprocessing step for intrinsic image decomposition and enhance the performance of the latter. A method of structure-texture separation using non-gradient-based descriptors is proposed. An alternative image smoothing approach based on the weighted least square (WLS) framework is especially proposed. The proposed approach incorporates the use of Feature Asymmetry (FA) which can better help locate the contours of objects. FA accurately distinguishes structures and textures as it simulates the response of the human perception system to step edges, contours and lines features, and is also sensitive to periodic patterns. WLS can better smooth out images by including FA as weights while preserving structures. Further, such techniques are employed in our phase-based WLS framework. The recent achievement at accelerating the solution of WLS by transforming the 2D optimization problem into two step recursive 1D optimization problems is used in this work to largely reduce the computation. The experimental results indicated that the proposed approach was effective for structure-texture separation and had low computational complexity, compared to state-of-the-art methods.

The third part of this dissertation explains how a fast intrinsic image decomposition method by using a near-infrared (NIR) image in addition to a RGB image for better decomposition performance was designed when the influence of fine textures exists. Many object's surfaces contain rich textures, especially those made of materials such as fabrics, plastics, metal and leather. These rich textures makes the problem of intrinsic image decomposition difficult. This is because most of the methods for intrinsic image decomposition largely rely on the edge of objects' structure which could be affected by the edge information of textures. In fact, the task of intrinsic image decomposition is to separate an input image into its material-related properties, known as reflectance or albedo, and its light-related properties which are referred to as shading or illumination. An effective algorithm of intrinsic decomposition heavily depends on the prior sparsity of edges with significant magnitudes in the albedo layer, which would be violated when there exist rich textures that contain a large number of edges of significant magnitude. To solve the problem, An NIR image that appears relatively textureless was adopted beside a RGB image, and a fusion strategy to reduce the influence of texture in the RGB image was designed, and then the feasibility of intrinsic decomposition was increased. The correlation between the RGB image and albedo layer was analyzed in our work through a chromaticity map and a pseudo-albedo map was defined based on both the RGB and NIR images that were included in a maximum-a-posteriori (MAP) model for intrinsic image decomposition. Here, a fast solver based on a half-quadratic splitting scheme and Plancherel's theorem was also proposed to efficiently solve our MAP problem using a fast Fourier transform (FFT). The proposed method outperformed methods of the state-of-the-art edge-based intrinsic decomposition and achieved fast computational speed.

Finally, a conclusion part is added for summarizing the main contents and contributions of the research work in this dissertation, as well as proposing the future potential extensions.