摘要

图像增强问题是数字图像和视频处理的一个基本问题。在图像采集的过程中，由于实际拍摄环境的限制，有相当一部分的图片是在光照不足的情况下获取得到的，这类图片通常伴随着噪声，其亮度和对比度相比于正常图像有大幅的下降，不仅大大降低了人眼的主观质量，还会造成一些信息的丢失，对后续一些以图像为基础的研究会产生很大影响。

针对这一问题，有大量学者进行研究，陆续的，多种算法被提出。考虑到低光照图像的噪声强度大大高于自然图像，并且图像的像素通常压缩在低的动态范围内，呈现出低亮度、低对比度的特性，因此，通常采用图像去噪、对比度增强的两步处理方式。在图像去噪的算法中，有常见的比较经典的双边滤波、BM3D 图像去噪法；在提升图像亮度、对比度的方法中，比较具有影响力的主要有以下三类算法：一类基于颜色恒常的 Retinex 理论，一类是基于图像统计直方图的直方图均衡化方法，还有一类受到了利用暗通道先验知识对图像进行去雾的算法的启发。随着深度学习的发展，一种基于全连接神经网络的方法 LLNet 被提出，并用于对低光照图像的进行增强。各种方法都尝试在保持图像纹理结构等内容信息的基础上，提高图像在人眼视觉系统的主观质量。

在本文中，首先阐述了该问题的研究意义，再针对低光照图像增强的相关领域进行了详细的调研和研究，提出一套完整的解决方案。受超分辨率卷积神经网络的启发，使用类似的网络结构对图像去噪进行了探究，在模型取得优于 BM3D 算法性能的同时，对于 512×512 的输入，在 GPU 上达到了 100 FPS 的处理速度。基于正常光照下图像所具有的统计先验，提出了基于亮通道先验的低光照图像增强算法，针对提出的模型，通过亮通道先验知识计算得到模型所需的相应的参数，代入模型求解。相比于现有算法，该算法在多项评价指标上均取得最优。另外，受全连接神经网络的增强方法 LLNet 和卷积神经网络的启发，将目前在计算机视觉领域中广泛使用的卷积神经网络应用到了低光照图像增强上，设计了一种特殊的卷积模块，并结合实际应用提出了一种新的损失函数。得到的模型在同样的数据集上进行测试，其 SSIM 指标比 LLNet 高了 0.194。

考虑到实际的应用需求，在本文中，还将针对现有的图像增强算法在对低光照图像处理后，在目标检测应用上的性能进行评测，并借此收集了一个真实低光照监控场景拍摄的数据集，在该数据集上进行测试，引入基于目标检测效果的图像增强评价标准。评测后发现，本文提出的基于亮通道的图像增强算法，在使用 Faster RCNN 作为目标检测方法时，对数据集中标注的车辆这一分类的 AP 值可以提升 2.95%。

关键词： 低光照图像增强，图像去噪，对比度增强，评价标准

Study on Low-light Image Enhancement

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ABSTRACT

Image enhancement is a basic task in image processing. When an image is captured by a camera, the environment light conditions vary from one to another. There are plenty of images captured under low-light conditions, usually at night. The image quality descends rapidly because of noise and loss of contrast. These images lack visual aesthetic. Also, for image analysis tasks such as object detection, image retrieval, etc., low-light images perform badly. Thus, low-light image enhancement is very important.

Low-light image enhancement is a long-standing problem, many scientists and scholars focus their attention on this problem, and various algorithms are proposed. In these solutions, considered that low-light images suffer from much more noise than those natural images which are captured under normal light conditions, and the pixel values of low-light images are usually in low dynamic range, the images appear to be in low quality and have low contrast. Thus, researchers usually use a two-stage processing method, namely image denoising and contrast enhancement. In the field of image denoising, there are several widely used methods such as bilateral filtering, BM3D and their follow-ups. To improve image contrast, various methods have been proposed and they can be roughly classified into three categories: methods based on retinex theory, histogram equalization (HE) algorithms, and methods inspired by dark-channel-prior-based dehaze model. Recently, deep learning based methods have made impressive progress in computer vision and image processing research community. And stacked denoising auto-encoder has been applied to enhance low-light images. All these methods try to enhance image contrast while preserve textures and details.

In this paper, a solution is proposed which consists of two parts, image denoising and contrast enhancement. Inspired by CNN based method in super resolutiuon, a CNN based method is proposed to do image denoising. This method achieves comparable results with BM3D and it can process 512×512 images at 100 FPS on a Nvidia Titan X . After that, the contrast of low-light images will be improved using contrast enhancement method. Two contrast enhancement methods are developed in this paper. The first one is based on atmosphere scattering model. Bright channel prior (BCP) is proposed, and by using BCP and a designed filter, transmission maps and the environment light in the atmosphere scattering model can be estimated. Hence, the final enhanced image can be calculated. The second one is a deep learning based method, enlighted by LLNet. Convolutional neural networks (CNNs) are used to enhance low-light images. A special module is designed so that the input image can be filtered by different filters. A novel loss function is proposed to train the model and this model increases SSIM value by 0.194 over LLNet.

In addition to the improvement of visual aesthetic feeling, a new performance metric is proposed to evaluate low-light image enhancement methods based on the results of current object detection algorithms. A new database is published which contains low-light images taken under insufficient light conditions by surveillance cameras. By using this novel performance metric, better algorithm can be found if it functions as a pre-processing procedure in image understanding problems. And the proposed BCP-based method increase the AP (average precision) by 2.95% for the category “car”, which is the state-of-the-art results in this testing database when using faster RCNN as the object detection method.

Key words: Low-light image enhancement, Image denoising, Contrast enhancement, Performance metric